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CONTENTS FOR JULY 1960

PAGE

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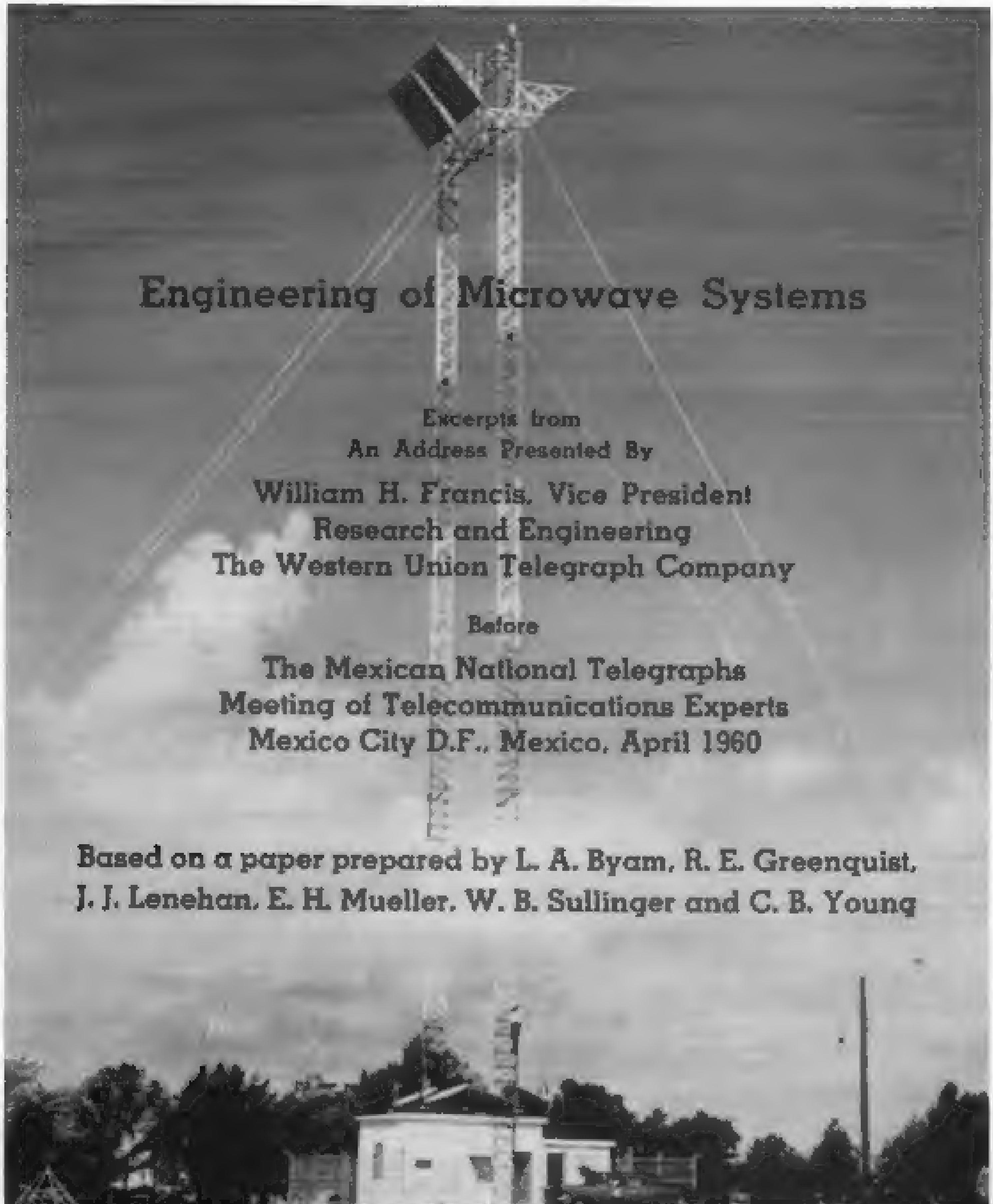
INDEX

For contents of Technical Reviews published previous to 1958, see separately printed Index for 1947 — 1957

For Index January 1958 — October 1959 see Vol. 13, No. 4, October 1959



Engineering of Microwave Systems

Excerpts from
An Address Presented By

William H. Francis, Vice President
Research and Engineering
The Western Union Telegraph Company

Before

The Mexican National Telegraphs
Meeting of Telecommunications Experts
Mexico City D.F., Mexico, April 1960

Based on a paper prepared by L. A. Byam, R. E. Greenquist, J. J. Lenehan, E. H. Mueller, W. B. Sullinger and C. B. Young

It should be emphasized that there are many advantages to be obtained by the use of a microwave system; however, to achieve the desired performance the system must be properly designed. With respect to economics, it is most certainly necessary to consider the maintenance costs very carefully. Means may be considered that will have the effect of reducing the first cost but they may also result in increased maintenance expense. It is especially important to weigh carefully all such factors in the large systems because of their complexity and the wide variety of conditions and environment in which they must operate.

Western Union and Microwave Relaying

Western Union started experimenting with frequencies in the 4000-mc band in 1945, and this work led to establishment of the first commercial microwave system for communications in the United States. Like any pioneering effort, the system encountered certain difficulties. Operating in the 4000-mc band, the output power was initially limited to 0.1 watt and there were fading outages. A program to develop a power amplifier was initiated and the 3-cavity SAC-41 Klystron tube shown in Figure 1 was the result. This tube with its nominal output of 10 watts greatly reduced the time lost due to propagation problems.

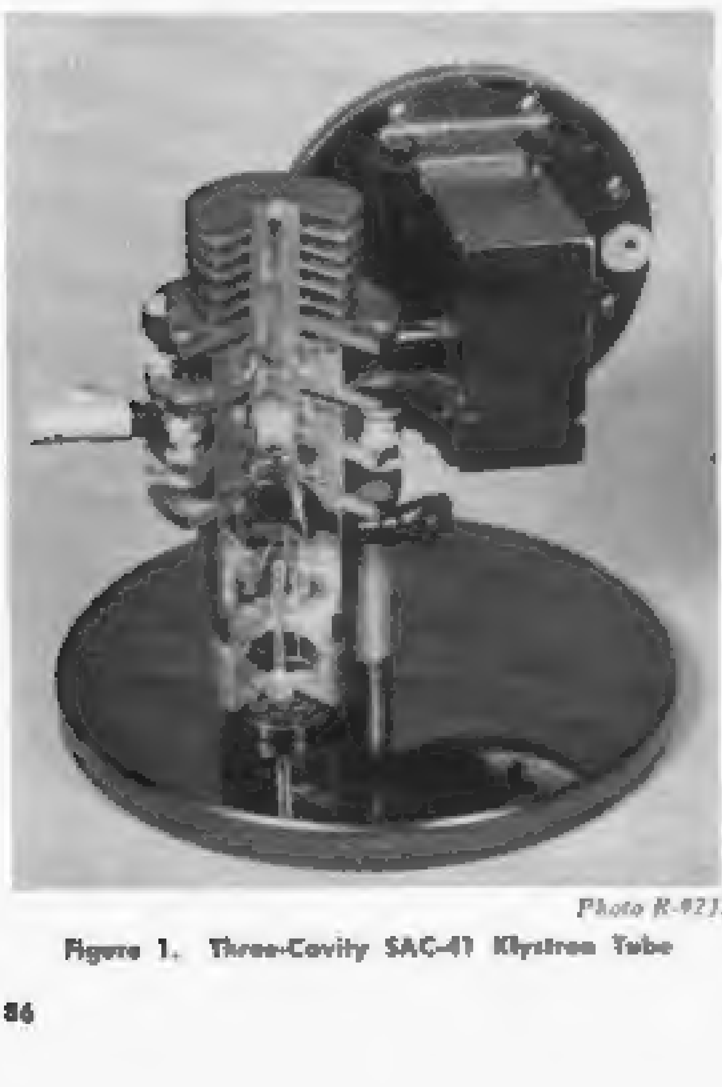


Photo R-9212

Figure 1. Three-Cavity SAC-41 Klystron Tube

In 1957 Western Union installed a 4000-mc relay system between Pittsburgh, Cincinnati, and Chicago, about 550 miles in length. Unlike its predecessor, it did not depend upon the triangle concept to provide fallback, but instead used a stand-by system that operated over the same route. The intelligence is transmitted simultaneously over the two systems and, at the terminals, the two signals are demodulated and an all-electronic combiner chooses the better circuit or combination of the two. Because the microwave frequency over each hop is different for each of the two systems, this layout provides frequency diversity for propagation as well as equipment fallback.

Currently Western Union is undertaking the construction of a 6000-mc system that will result in a transcontinental circuit approximately 3700 miles in length with 12 drop and insert points on the trunk route. It is shown in Figure 2, and consists of a working system with 100-percent stand-by, the same as the Pittsburgh, Cincinnati, Chicago system, and is capable of providing 600 voice-frequency channels. Each of these channels may be divided into as many as 20 frequency-shift telegraph channels, providing a telegraph capability of 12,000 channels. Actually, the capacity will be divided between voice, telegraph, facsimile and high-speed data as requirements dictate.

A one-way video channel having a minimum 6-mc bandwidth will also be provided over the same route. One-for-one fallback is applied to the video in the same manner as described for message channels. This channel will also operate in the 6000-mc band and will use the same antennas, towers and buildings as the communication system. The route, for reasons of national defense, avoids all known target areas. Connecting the back-

bone route to the major cities will be tributary systems operating in the 4000-mc common carrier band. These tributaries will have a capacity of 120 voice channels, or 2400 telegraph channels.

Western Union is planning additional routes and, as a pioneer in microwave relaying with broad experience in all phases of the problem from design to operation, has confidence in its ability to provide economical and reliable transmission facilities that will meet the needs of its customers. The company has also been investigating the technical and economic aspects of satellites for communication. The study is not yet complete but indications are that this method of communications is more attractive for spanning oceans than for land areas where point-to-point microwave systems can be installed. No doubt there will be communication via satellites within the next decade but it will complement rather than make obsolete present-day transmission systems.

Figure 2. 6000-mc transcontinental relay system

System Characteristics

It is customary to specify the noise performance of a transmission system in one of two ways. The first is signal-to-noise ratio while the second is the measurement of noise compared to some noise reference level. The latter measurement is quite common in the telephone field where the audio level is determined by the talker. When the point of measurement is known, however, it can be converted readily to a signal-to-noise ratio with the reference usually being accepted as 0 dbm. In order to avoid the complications of weighting, transmission level points, and other factors, this discussion will be limited to a consideration of the first method, that is, signal-to-noise ratio.

If, for the moment, the term "noise" is assumed to include any unwanted electrical disturbance, there are three major types of noise in a microwave system. These types are called white noise, impulse noise and crosstalk. The first, white noise, is produced primarily in the input circuits as thermal noise and in the first stages of the receivers and amplifiers. White noise has a characteristic that is flat with frequency at the input to the radio-frequency equipment and produces noise that rises at the rate of 6 db per octave in the demodulated baseband. The second, impulse noise, which is especially harmful to high-speed data, is usually picked up in the lower frequency sections of the transmission system or equipment and may be caused by manmade transmissions. This type of noise does not always occur as a single spike but may be spread over time periods several times the length of the shortest signal pulse in a given bandwidth. Lightning, sunspot disturbances, or similar natural phenomena do not produce harmful impulse noise at microwave frequencies. The third source of noise is crosstalk. It results from harmonics and sum and difference products of baseband frequencies produced by equipment nonlinearities as the intelligence is transmitted from station to station. This can also produce noise peaks similar to impulse type noise.

Let us now analyze what can be done to minimize these sources of noise, and learn just what limitations we face in the current state of technology. The effect of white noise can be greatly reduced by careful design of the first stages in the radio receivers. At present, microwave receivers with wide bandwidths operating in the 4000-mc and 6000-mc ranges are most likely to have noise figures of 10 to 13 db. That is, the noise at the receiver output is 10 to 13 db greater than it would be if only thermal noise were present at the input terminals. The signal-to-white noise ratio can be increased by higher transmitter powers and larger antennas. Tubes capable of delivering a kilowatt or more at 4000 and 6000 megacycles have been designed and constructed. However, economics as well as technical considerations dictate that output power for line-of-sight systems be limited to 5 to 10 watts; this together with reasonable antenna sizes is adequate to meet most performance requirements.

Antenna size is limited for two reasons. The first reason is economic and is fairly obvious. Not only do large antennas cost more but the tower that mounts them must be sturdier, and the sharper beam widths that go with increased size can tolerate less tower twist and tilt. A somewhat less obvious limitation results from the mechanics of propagation. The signal at a receiving antenna of a line-of-sight system often arrives over one or more paths simultaneously. At any instant, the receiver operates on the vector sum of these signals. Because they have traveled over paths of slightly different and varying lengths, the vector revolves and changes amplitude rapidly. While any one of these signals can be going rapidly from a relatively high to a low level, probability dictates that the vector sum is usually close to the theoretical value. If antennas are increased in size, their discrimination of these signals is increased. The result is a greater signal when the energy is arriving right on axis, but deeper and more frequent fades during times of multipath transmission. A good compromise between gain and multipath fading for line-of-sight microwave dictates antennas with apertures of about 10 feet for frequencies up to 6000 or 7000 mc.

A very serious source of trouble in some early systems was spurious radiation produced in the equipment itself at a frequency which coincides with one of the intermediate-frequency (i-f) amplifiers. This resulted from the multiplication of a basic crystal frequency to the desired microwave frequency for local oscillator or transmitter drive. Another source of trouble was spurious signals generated in microwave diodes or tubes. Feedback at harmonics of the microwave frequencies has also been known to cause trouble when the waveguide filters did not provide all the rejection needed. Another source of interference is overshoot from one station to another several repeaters beyond. Since it is customary to reuse microwave frequencies every few stations, the possibility of one station transmitting into another several repeaters away is very real in mountainous areas and during periods of abnormal propagation. To avoid this, it is desirable to stagger the lines from repeater to repeater by not less than 5 degrees.

The other cause of impulse noise mentioned earlier resulted from other man-made transmissions. These include such things as radar, aviation beacons and navigational aides, medical equipment, and other industrial devices. While some of these are not likely to be important in remote areas, they are very important in centers of large populations.

The third principal source of noise, crosstalk, is probably the most difficult to predict and to guard against in a broadband multichannel system. In a circuit of great length, there will be many modulations to radio frequency and demodulations to baseband. Since each such modulation and demodulation will add a certain amount of distortion, the design of these units must use every technique known to achieve maximum linearity. All equipment will require the highest caliber of maintenance with the help of excellent test equipment to keep it in proper operating condition. Other sources of crosstalk are amplitude and phase nonlinearities in the repeaters. If each repeater were

absolutely flat in amplitude and linear in phase, all the sideband components produced by modulation of the r-f carrier would pass through in correct relationship to one another. Since it is impractical to achieve this ideal condition, the relative amplitude and phase of these components are disturbed, and this manifests itself as intermodulation distortion or crosstalk. Careful design and the ability to measure and maintain amplitude linearities in a repeater to within 0.1 db over the 20-mc to 30-mc r-f bandwidths required for long systems help to minimize this effect. Relative delay variations are measurable and correctable to about 1 millimicrosecond over comparable bandwidths; however, the delay will change with ambient conditions, so relative delay becomes one of the most important factors in the performance of a long multihop system.

Antennas and Transmission Lines

A very important part of any microwave system, from the standpoint of performance, is the antenna and its transmission line. The passive reflector system is economical where tall towers are required, as long feed lines are eliminated. The reflector itself is capable of handling any polarity and any frequency since it is simply a flat metallic sheet. Polarity and frequency become a problem only when the feed or illuminating device is considered. The parabola mounted at the top of a tower requires a transmission line and, hence, is a more expensive arrangement than the passive reflector system but does not require as sturdy a structure as the horn reflector.

One of the advantages of the horn reflector is its low rear lobe radiation characteristic. This is of importance where it is desired to use the same r-f channel for transmitting or receiving in opposite directions at the same station. For example, the 5925-mc to 6425-mc common carrier band may be divided into sixteen 30-mc r-f channels. With horn reflectors, it is feasible to carry eight two-way r-f channels simultaneously at each repeater. However, if passive reflectors are employed, this number becomes four two-way channels because of the coupling between the antenna systems on opposite sides of the tower which necessitates using different frequencies to obtain the decoupling required.

One important technical consideration that favors passive reflectors is the elimination of long transmission lines that are a source of echo distortion. When an antenna and its associated transmission line are not perfectly matched, the reflections produced are transmitted, displaced in time, from the fundamental radiation itself. This phenomenon, called an echo, produces distortion that can have a detrimental effect on system performance. The extent to which it is a problem is related to the transmission line length and to the modulating frequency. A wide-band system employs high modulating frequencies and the length of the transmission line would be critical. With passive reflectors, the line length between transmitter output and antenna, and receiver input and antenna, can usually be kept to within about 20 feet. On the other hand, tower-mounted parabolas or horn reflectors might require several hundred feet of line. When such long runs are necessary, special measures must be taken to reduce echo effects.

Western Union plans to use a passive reflector antenna system on the transcontinental circuit now being installed, except in locations where towers are not needed and the parabolas can be mounted on top of the equipment building. In a 500-mc bandwidth at 6000 mc a total of four two-way channels can be obtained. These channels may be used in a number of ways. They may provide two 600-voiceband circuits, for example, each with 100-percent stand-by, or one 600-voiceband circuit with 100-percent stand-by and one video channel with 100-percent stand-by, or three 600-voiceband circuits with one stand-by. In each of the above examples, a circuit, whether it be used for message or video, is a two-way circuit. It is Western Union practice to design the r-f filters and equipment so that a total of eight two-way r-f channels may be obtained in the 500-mc band at 6000 mc by changing the antenna system. The r-f

channels are 30 mc wide and spaced 29.7 mc between center frequencies. The allocation plan calls for all transmitters at a station to be located in one half of the band and the receivers in the other half. At the next station, the position of the transmitters and receivers in the band is reversed. In the 500-mc bandwidth at 4000 mc the r-f channels are not grouped into two blocks, one for transmitters and one for receivers, but alternate channels are used for transmitting and receiving. This permits six two-way r-f channels spaced 40 mc between center frequencies, each of which is suitable for handling 600 voice channels.

There is very little choice, technically, between the 4000-mc and 6000-mc bands. Both are high enough in the spectrum so that reasonable size antennas may be used to obtain the gain required. Wide-band tubes with the necessary output power are available. The 6000-mc band may be slightly poorer from a propagation standpoint but, with diversity and adequate fade margin designed into the equipment, this does not present a serious problem.

Propagation and Site Selection

The matter of site selection and the choice of repeater locations for optimum propagation performance is of major importance in establishing a microwave system. The criteria specified by Western Union for path clearance are 1/3 first Fresnel over all obstacles, with the profile plotted on 2/3 true earth radius. A path having such clearance is illustrated in Figure 3. If practical, the terrain for line-of-sight circuits should be so chosen that areas with a high reflection coefficient are avoided. When this cannot be done, it may be possible to adjust the tower heights at each end so as to minimize the reflection problem.

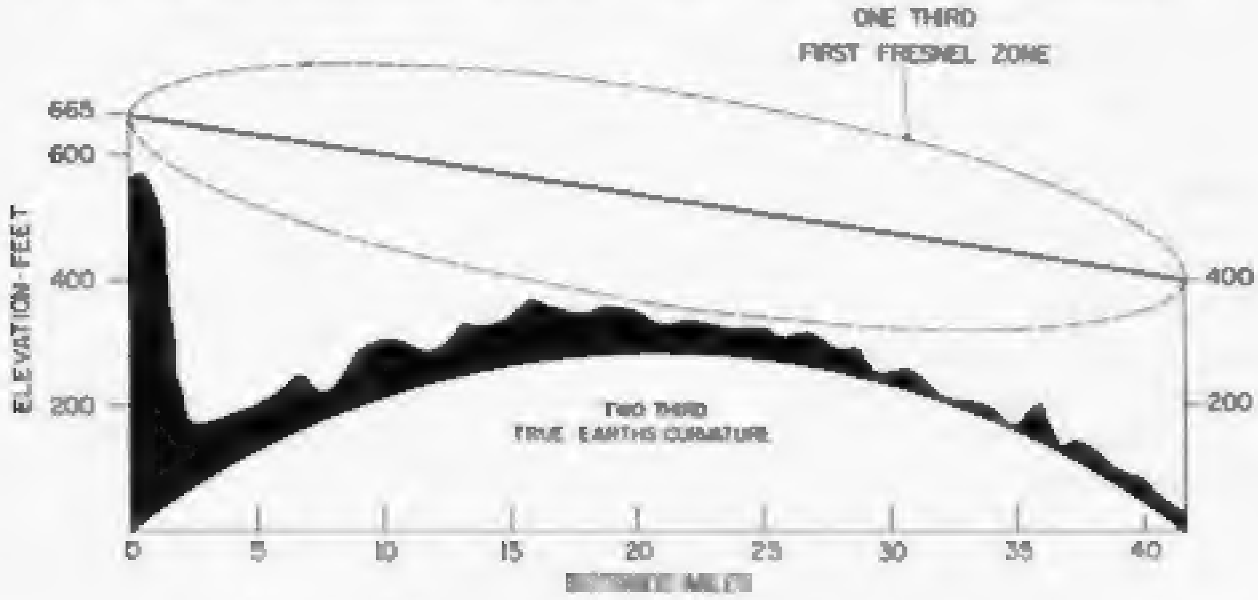


Figure 3. Microwave clearance path above earth's surface

Caution should also be exercised in establishing path lengths, and it is Western Union practice to limit the average length to between 25 and 30 miles for long high-quality systems. The maximum length often resolves itself into a matter of judgment, and a competent propagation engineer should be responsible for making such decisions.

In addition to the problem of reflection described above, there is multipath transmission through the atmosphere itself which produces rapid variations in the received signal strength. In addition to fading due to multipath transmission, there may also be a gradual drop in signal level due to bending of the main ray. This phenomenon is often called reverse bending because it can be considered as equivalent to the earth rising into the path. In Figure 4, the curvature of the earth for flat, true earth, 4/3 radius, and 2/3 radius is shown. Intervening terrain has been omitted from this figure to avoid confusion, but it can be readily seen that an obstacle which does not interfere with transmission on a 4/3 true earth radius might block line of sight on a 2/3 earth radius.

The most serious propagation problems occur when rapid multipath fading is superimposed on that caused by reverse bending. After a system has been designed with practical transmitter power, receiver noise figure, and antenna size, little can be done to guard against reverse bending except possibly increasing the path clearance. Obviously, there is a limit to this, and since fades due to this cause alone are seldom severe enough in a properly designed system to produce circuit outage, the emphasis is usually placed on minimizing the effects of multipath propagation.

Figure 4. Comparative curvature lines

Two ways to accomplish this are space diversity and frequency diversity. Space diversity requires the separation by several wavelengths of a pair of transmitting or a pair of receiving antennas. Frequency diversity employs a common antenna at each end, but two different frequencies are transmitted. Frequency diversity is effective if a difference of about 4 percent of the normal operating frequency is employed. At 4000 mc this would be 160 mc, while 240 mc would be required at 6000 mc. When closer spacings are used, the fading on both channels will be more closely correlated. Western Union has successfully employed both forms of diversity, but its current expansion program will use frequency diversity as it also provides protection against equipment failure.

In addition to the technical considerations involved in site selection, there are other problems such as accessibility, power availability, soil conditions, availability and cost of land, existing structures, zoning regulations, airports, unusual weather conditions, and others that must be evaluated. These factors bear heavily on the economics of a system.

Power and Buildings

In selecting sites, it is desirable to locate near reliable commercial power if at all practical. This avoids the installation of expensive primary power plants but does not eliminate the need for emergency power for, during periods of severe icing or wind storms, commercial power can be cut off for several days. When such outages do occur, it is the responsibility of the emergency power plant at each station to keep the system operative. Western Union specifications require that the switchover during times of power failure be accomplished without interrupting service.

The type of emergency power plant that has proved successful and is used in the newest installation appears in Figure 5. This is a three-unit machine consisting of an a-c motor, an a-c generator, and an internal combustion engine. Under normal operating conditions, the commercial power drives the generator, which provides 60-cycle, 115-volt, single-

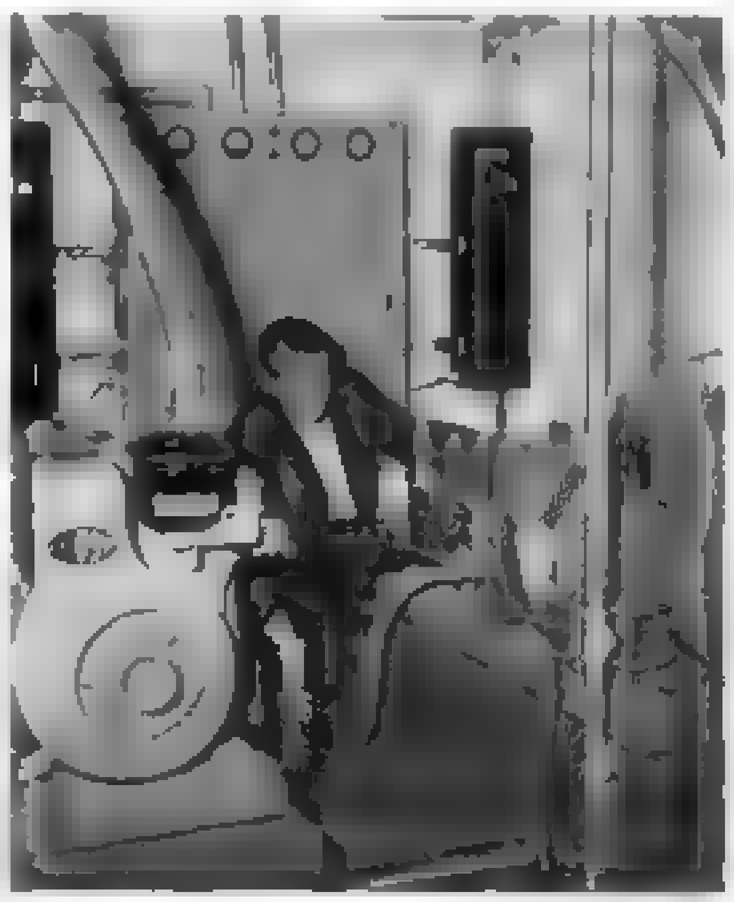


Photo H 2184

Figure 5. Emergency power plant

phase regulated a-c power for the radio. When the commercial power fails, a magnetic clutch connects the generator to the engine mounted on the same shaft axis. The inertia of the machine is sufficient to keep the potential up until the engine starts, thereby preventing any interruption to the radio transmission.

In the Pittsburgh-Cincinnati-Chicago installation, one of these machines is provided for each of the two circuits. In the event of failure of either machine, the circuit associated with it is transferred to the other unit, thereby providing emergency power fallback. This is in agreement with the philosophy followed for both equipment and propagation, that fallback protection be on a one-for-one basis.

In areas where commercial power is not available, diesel engines are recommended as the prime movers for the generators. Here again, economics and reliability are the determining factor. Nuclear power plants should not be overlooked as an attractive possibility for stations in remote areas if the installation is more than five or ten years away. The obvious advantage of nuclear power is that fuel deliveries and maintenance are essentially eliminated.

Buildings to house the equipment at the sites are usually of masonry. Sufficient space is provided to allow for expansion, and stations where maintainers are normally stationed are usually larger and provide work and storage space. The ceiling height is great enough to permit adequate clearance above the highest rack and waveguide runs. The roof is capable of supporting the antenna and any snow and ice which may be expected. In areas of heavy snow, it may be desirable to provide an entrance through the roof. Air conditioning may be desirable in tropical areas, and heating in high-altitude cold climates. In inaccessible locations, the power units may be located in a separate building near a road to facilitate refueling.

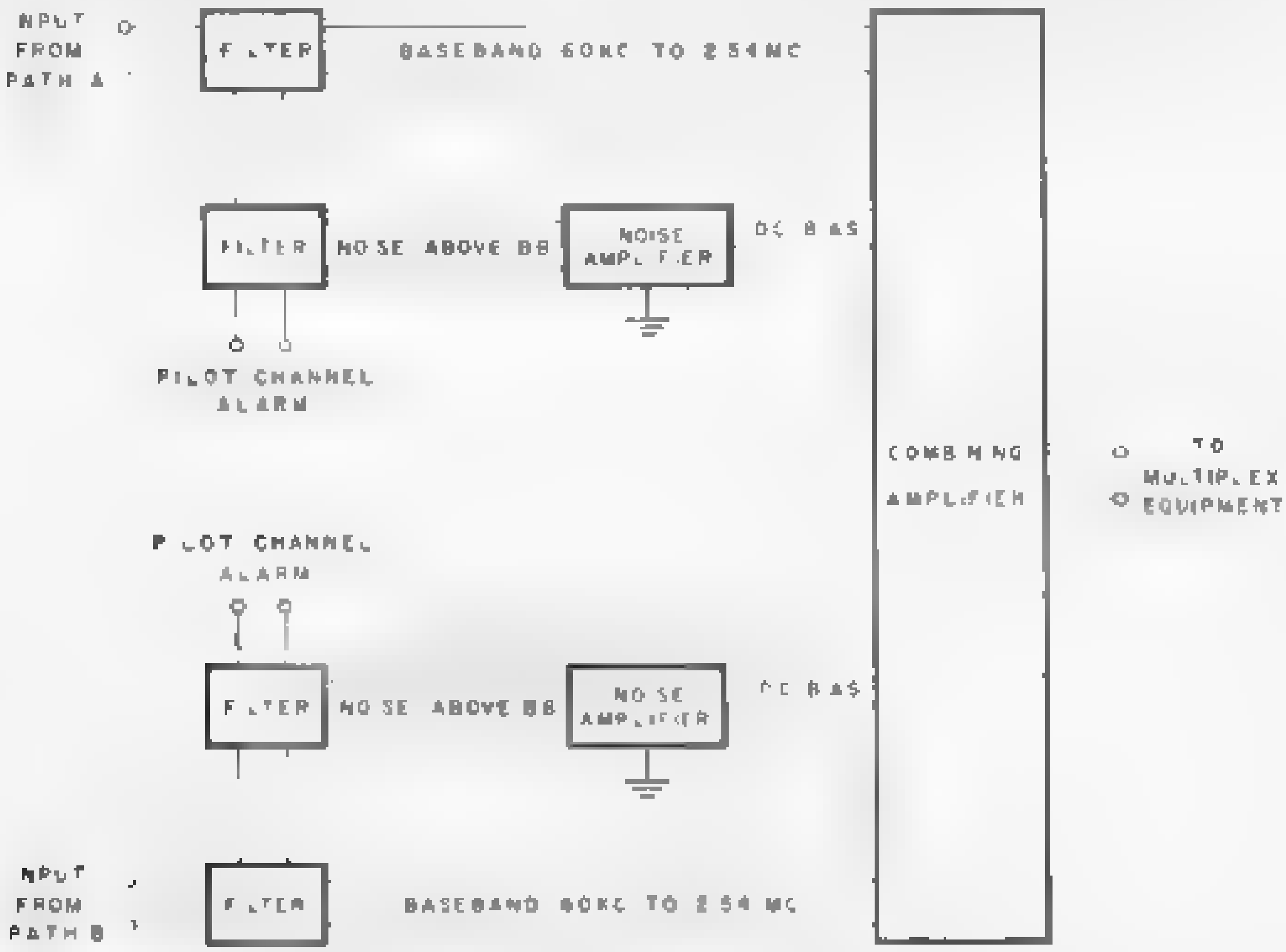


Figure 6. Block diagram of baseband combiner

Diversity Operation

The use of space or frequency diversity, as mentioned earlier, requires a means of automatically selecting and operating on

the better circuit or combination of circuits. Two methods of accomplishing this are baseband combining and baseband switching. Figure 6 is a block diagram of a baseband combiner used at the terminal. In this diagram, it is assumed that the 600 voice channels are stacked between 60 kc and 2.54 mc by frequency-division multiplex equipment. The same intelligence is modulated on two transmitters at the distant terminal and travels the system length over the same route, but each of the parallel paths uses a different microwave frequency for each hop. This combination provides equipment as well as propagation fallback. In the event of a fade in any section, a corresponding increase in the noise would be noted in the traffic channel. In order for the combiner to recognize this, a channel out of the baseband is provided for monitoring noise on each system. If propagation is normal on both legs, the noise will be approximately equal in each system and the two outputs will be combined and fed to multiplexing equipment at the receiving terminal. When the noise in either circuit increases, as measured outside the baseband, it is detected and used to reduce the gain and, hence, the output from the noisy circuit. At the same time, have an estimated maximum rate of 100 db per second it is possible to set the switchover recognition point 1 or 2 db above the failure point and still switch satisfactorily with recognition times as long as 100 microseconds. Although the switching time given above is quite satisfactory for voice, errors may be produced in high-speed data channels. The switch has a disadvantage compared to a combiner for fading as it is always desirable to be on the better of the two circuits, and thus can be approached only by making the required switching differential between the circuits small. As this differential is decreased, it results in a larger number of switch operations which, in turn, may produce errors in the high-speed data channel.

Associated with each of these methods of diversity operation is the problem of failure at the receiving terminal. If this occurs, the failed circuit would actually be the quieter and either the combiner or switch would choose this circuit for operation. To prevent this, a pilot frequency is transmitted over the circuit and, in the event of a failure, the pilot alarm operates and locks the baseband output to the system that has a pilot tone.

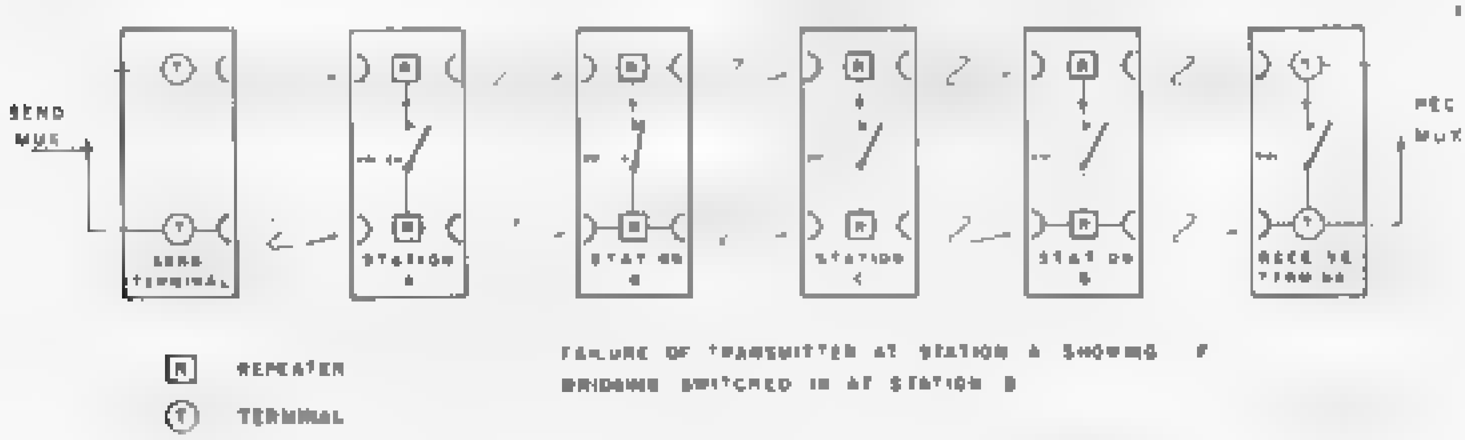


Figure 7 Heterodyne repeater system employing i-f switching

the gain of the satisfactory circuit is increased so as to maintain a constant output.

A high-speed baseband switch, like the combiner, recognizes out-of-baseband noise and effects a switch to the quiet circuit. At present, the switch travel time can be in the order of 10 microseconds with solid-state devices. Because fades

An additional method of increasing reliability employs i-f switching at each repeater. In Figure 7, a terminal-to-terminal section is shown with a break occurring in one circuit because of a transmitter failure at repeater A which would make the circuit inoperative beyond that point. With i-f switching, the stand-by is available beyond station B.

Reliability

The over-all reliability of a microwave system is determined by many factors, including system design considerations, the quality of the equipment, and maintenance. As discussed above, it is necessary to use two radio channels in parallel with automatic combining to provide the continuity of service required on a long system. In addition, maintenance should be of a preventive nature, since the number of tubes alone is so great that even with a mean tube life of ten thousand hours, if they were allowed to run until they failed, the interruptions would be so frequent that the system would not be satisfactory

The reliability of a system can be illustrated by assuming a circuit approximately 8600 miles in length with 286 hops which include 62 terminals where there is demodulation for dropping and inserting channels. This is an average of approximately five hops between terminals. Assuming equipment that has a mean time between failure of 2500 hours, and with maintenance such that the time to correct failures averages 2.5 hours, a single system end-to-end would be in a failed condition because of equipment about 44 percent of the time. By providing two channels, as discussed above, with automatic i-f switching at each repeater and combiners at the terminals, the probability of system failure is greatly reduced and the reliability due to equipment alone will be 99.97 percent. With a fade margin to the failure threshold of 35 db in each hop, the over-all equipment and propagation reliability of the system will be 99.91 percent. A change in any of the parameters assumed above will substantially affect the reliability figures quoted

Fault Locating and Maintenance

One of the auxiliary facilities that must be provided for the maintenance and operation of a system is equipment to monitor and control unattended repeater stations. Considering a long circuit having an average of five hops, or four repeater stations, between terminals, the operation of equipment at these stations must be monitored in sufficient detail to permit supervisory personnel to dispatch maintainers to the proper location when a failure occurs. Depending upon the economics and operating practices, it may be desirable to extend this remote control to some of the terminals. It is technically possible to consider operation of a network connecting 60 cities, with supervision and control by personnel stationed at 10 to 20 key points.

A minimum system for fault locating on a microwave system required to provide high reliability is one that sends sufficient information to a supervisory point to permit identification of the station at which trouble has occurred. The most important information from a remote relay station is whether or not the transmitter output power is normal. In some systems, such as those employing automatic switching between the receiver and the transmitter to bypass defective equipment, it is also necessary to know whether or not the receiver output signal is normal. Ancillary alarm signals may be required for troubles requiring specific action, i.e., failure of primary power, failure of tower lights, or building entry. Two additional alarms covering the broad categories of "condition requiring immediate attention" and "condition requiring attention but not on an emergency basis" will usually cover all other requirements at a remote station that does not have diversity switches, combiners, or carrier multiplex equipment

At unattended stations that demodulate to baseband, additional monitoring is required to cover failures of modulation amplifiers and other units in the circuit at those points. Furthermore, to minimize the degradation in the reliability of the system resulting from the extra equipment at these stations, stand-by units are customarily added that may be switched into service. Remote controls must generally be provided to permit connection of these equipments into the circuit as required by failure of other parts of the system. This further increases the number of conditions that must be monitored, the increase depending upon the type

and degree of equipment redundancy provided

Voice circuits must be provided to permit communication between supervisory stations and remote stations. Other private circuits connecting some or all of the supervisory stations are also desirable. Provisions for interconnection between these circuits, standard voice circuits, and/or base station equipment for mobile radio systems are desirable features for the supervisory voice communications network.

Other circuits and equipment for transmission of written orders and records for monitoring the quality of operation of the system complete the most desirable aspects of the monitor-and-control equipment for a high-quality microwave communication system. These facilities may all be provided on the microwave system itself with a degree of reliability as good as or better than that of the traffic channels being carried. Such equipment provided for one system on a route can also serve to monitor and control other systems on the same route.

Any communication system, no matter how well planned and engineered, is dependent upon maintenance for satisfactory performance. Although the designer's objective is to realize an equipment that can be maintained by personnel with a minimum of training, the minimum standards for maintainers of microwave radio equipment are high. Poor performance of a microwave system may well be due to the sum of degradations in a number of repeaters. Any one station in a multihop system can operate significantly below its design objective without affecting over-all performance appreciably. It is essential, however, that each station be maintained to a standard or there will be a gradual deterioration in over-all performance that will require a time-consuming and expensive realignment at all stations.

Western Union has established a three-echelon organization to maintain microwave equipment. The first of the three levels is comprised of on-the-site maintainers who are each responsible for three to five stations. Supervising them are engineers on the professional level who are located in area subdivisions. Finally, a home office staff of experts exercises over-all control and handles complex problems.

Multiplex

Frequency-division multiplexing is accepted as the best method of channelizing broadband microwave systems. The major reasons for this are reliability, superior performance, and the relative ease of maintenance. To realize all the advantages of frequency-division, however, there must be standardization of certain parameters. The most important of these are over-all baseband frequency capability, common frequency allocations for individual channels, basic groups, supergroups, and line groups; common acceptance of levels and impedances; agreement on choice of pilot frequencies; agreement on permissible white noise and intermodulation introduced by the multiplex; and ambient operating conditions.

A considerable amount of work in standardization has already been done by CCITT (Comité Consultatif International Télégraphique et Teléphonique) and CCIR (Comité Consultatif International Radio). Table I is their recommendation for frequency allocation, impedances, and operating levels which is generally followed by Western Union.

Some of the more important requirements for a four-wire voice-frequency channel derived from a frequency-division multiplex system tested on a back-to-back basis are given in detail in an appendix. It should be pointed out that these requirements are directed primarily towards telegraph and data transmission rather than voice; therefore, they place tighter tolerances on such things as frequency displacement and amplitude-frequency response.

The Western Union standards for a 600-channel multiplex equipment follow CCITT allocations in that the frequency spectrum for the baseband must be confined to from 60 to 2540 kc and that the primary subdivision of the baseband spectrum is on the basis of ten 60-voiceband supergroups. These basic supergroups are divisible into five 12-channel base

groups. Under some circumstances, it is desirable to divide the base group further into three 4-channel pregroups.

To provide drop and insert channels at intermediate points and to transfer groups of channels at these same points, requirements are specified; for example, the equipment shall be capable of six supergroup transfers and eight base group transfers without losing any telegraph channels assigned to the voicebands or without any interference between groups. This makes the most efficient use of the available spectrum. In addition to voice-width channels of approximately 300 to 3600 cycles that are used for telegraph, facsimile, telephone, and data, arrangements are also made to obtain wider bands for higher speed data transmission. Some of these bandwidths are 16, 48, 96, and 240 kc.

In many instances, the initial traffic requirements may not justify installing a complete 600-voiceband multiplex system, although the microwave equipment is capable of handling 600 or more voice channels. Thus, the number of channels may be increased as the demand dictates by adding carrier multiplex equipment at the terminals. In a complex system having many points where channels are dropped and inserted, proper advance planning is necessary to avoid interrupting the system for an appreciable length of time when additional carrier multiplex equipment is installed and placed in operation.

TABLE I

Maximum Number of Telephone Traffic Channels	Frequency Limits of Baseband KC/S	Nominal Impedance at Baseband	Relative Power Level Per Channel DB	
			Input	Output
24	12–108	150 Ohms, Bal	−52	+4.5
60	12–252	150 Ohms, Bal	−52	+1.75
	60–300	75 Ohms, Unbal	−52	−15
120	12–552	150 Ohms, Bal	−52	+1.75
	60–552	75 Ohms, Unbal	52	15
240	60–1052	75 Ohms, Unbal	52	15
600	60–2540	75 Ohms, Unbal	−52	−15

Larger capacity systems are not excluded by the above table

Standards

A problem of fundamental importance in establishing a communication network having international terminations is the matter of standards. It must be possible to operate telegraph, voice, data, facsimile, and television between any points on the system and, presumably, there will have to be connections with other networks

In a microwave system, it is not necessary to use radio equipment of the same manufacture throughout, although it may be desirable from an economic standpoint. Standards may be set up for r-f channel assignments and allocation, r-f bandwidth, r-f deviation, r-f stability, i-f assignment and bandwidth, baseband width, baseband signal-to-noise, and baseband distortion, to name some of the more important factors, so that uniform performance and compatibility exist in all sections of the system. It is, of course, possible to connect a microwave system to a cable system at baseband with suitable compatibility and standards so that the network is a mixture of the two forms of transmission media. This is not necessarily recommended but is cited as an example of what can be done with standardization.

The baseband is normally divided into a number of voicebands by frequency-division techniques. When used for voice or data, the levels, impedance, and signaling parameters are important at the interconnection points. When these channels are used for facsimile, the amplitude and delay characteristics of the circuit become important considerations. If telegraph is a requirement, then the voice channel is further subdivided by carrier methods using 120-, 150-, or 170-cycle spacing. The Western Union standard is 150 cycles, and 170 cycles is also widely used in the United States. When operating telegraph between two terminals of a microwave system, the carrier side of the telegraph channels must have the same channel spacing and other characteristics. This has to be arrived at by agreement as there is no outstanding technical reason upon which a decision can be based

High-speed data requires the same standardization as telegraph. If transmission problems are to be held to a minimum, the data terminals should employ signaling rates that can be handled by the available communications channels. A proposal now before the Electronic Industries Association in the United States recommends that standard signaling rates (S) be determined from the following formulas:

$$S = 150 \times 2^n \text{ bauds}$$
$$S = 900 \times 2^n \text{ bauds}$$

where n may be zero or any positive integer

The signal element duration recommended by the same group can be found from

$$\text{Signal element duration in seconds} = \frac{1}{\text{Signaling rate in bauds}}$$

There has been much work done by CCIR, CCITT, and the Electronic Industries Association on standards, and it is recommended that this work form the basis for the standardization of circuits having international connections. It is likely that standardization will be expensive in some instances but the long-term advantages cannot be measured in terms of initial cost.

* * * * *

The treatment given this entire subject has, of necessity, been general, but somewhat more detail is included in an appendix which it is hoped can be published in a future issue of TECHNICAL REVIEW

WILLIAM H FRANCIS joined Western Union in 1921 as an installation engineer after graduating from Stevens Institute of Technology with an M.E. degree. He advanced through positions in the engineering department and in 1946 became director of applied engineering. In this capacity he had a major role in the engineering of Western Union's plant mechanization and modernization throughout the United States. Following his appointment as assistant vice president, engineering and installation, in 1955, he coordinated the engineering manufacture and installation of the fully automatic global communications system now being provided for the U.S. Air Force. Mr. Francis became vice president, research and engineering, on January 1 1960 He is a member of Tau Beta Pi

RICHARD L. EMERSON, Project Supervisor

Switching System Equipment Testing Plan 55

Development of efficient maintenance methods and design of specialized maintenance tools—or instruments—may be as important for successful functioning of a modern continuously operating complex of machinery and electronic controls as is soundness of design in the primary apparatus. Nowhere is this more evident than in the ever broadening application of automatic devices to telegraphy.

DESIGNED to meet the requirements of the United States Air Force, the Western Union Plan 55 automatic message switching system is built around the "swap-out" method of maintenance. Every relay, electronic circuit, and mechanical unit is built with plug-in connections allowing it to be removed from the line when a trouble condition occurs. This system of maintenance creates a need for extensive testing facilities in order to duplicate as nearly as possible the actual operating circuits of the plug-in units. The test circuits for Plan 55 have been built into four separate test tables and an associated equipment rack.

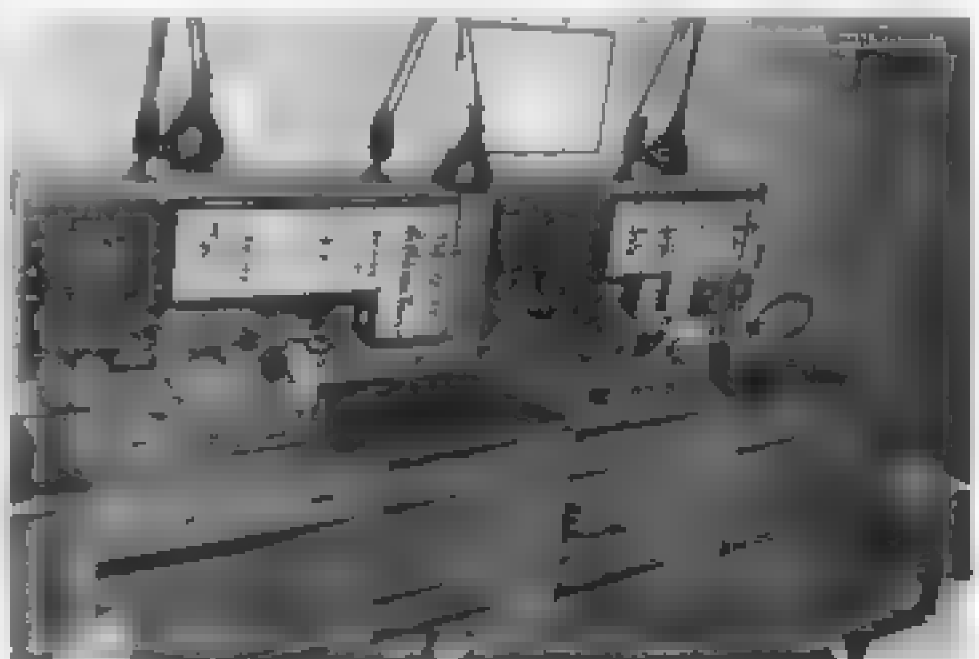
TEST TABLE 9412-A

This test table is designed to check the operation and reliability of the following electronic units: SNI (Sequence Number Indicator) Control Bank 7625-B, Message Waiting Control Bank 7626-B, and Electronic Character Readers 7700-A, 7700-1-A and 7701-A. It will test these units under dynamic conditions with associated mechanical equipment, or under static conditions without any other associated equipment. The dynamic tests are more nearly identical to the actual operating conditions and should be used, of course, whenever possible.

The output terminals of the electronic unit being tested are terminated in a resistance load shunted by a neon indicator lamp to give a visual indication whenever an output circuit is activated. For dynamic tests, the input terminals are terminated in the appropriate piece of mechanical apparatus, i.e., LBXD Model 28 Transmitter-Distributor, LPR Model 28 Typing Reperforator, or Loop-Gate Transmitter 7595-A. Yaxley switches are provided for properly terminating the input circuits to perform static tests.

By using the appropriate test tape in the LBXD or the loop-gate transmitter, the dynamic tests can be repeated rapidly and efficiently enough to determine if intermittent or marginal troubles exist in the unit being tested. The static tests are more cumbersome to make and less likely to show up intermittent troubles.

Dynamic tests of the character readers and the message waiting control bank re-



Test Table 9414-A and Test Table 9412-A

quire constant observation of the visual indicator lights and, therefore, the test tape should be perforated so that the visual indicators are operated in a geometric pattern. Extraneous characters can be inserted between the output characters when testing character readers to slow down the movement of the established pattern from light to light enabling one better to observe a failure

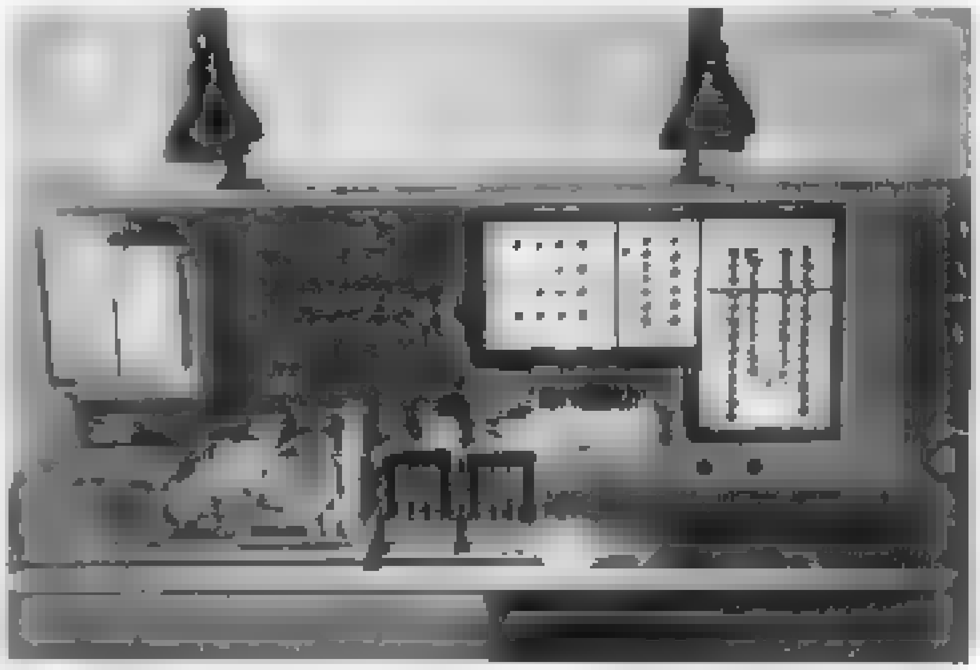
Sequence Number Unit Tests

The right and wrong comparison circuits of the SNI control bank can be tested completely and dynamically with ease on this test table For the right comparison test, a switch is provided to "tie together" the two signal inputs to the comparison circuits. These two inputs are then pulsed by the loop-gate transmitter. As this removes the need for a given character sequence being fed to the comparison circuits, any failure to make a right comparison must necessarily be due to failure of the comparison circuits themselves. The nature of this test allows one to use a loop tape in the transmitter, and leave it running unattended

The table is designed to provide an auto stop in case a failure to compare correctly occurs. In testing the wrong comparison aspects of this unit, the auto stop arrangement is changed to operate when the unit detects a *right* comparison. The SNI control bank input circuits are conditioned to supply the pulses from the loop-gate transmitter at only one of the two inputs and to supply a steady blank character at the other input circuits. A test tape containing no blanks is used in the loop-gate transmitter providing a wrong comparison condition continuously at the inputs to the SNI control bank, thus preventing the auto stop unless the comparison circuits should erroneously record a right comparison condition, in which case the auto stop would occur.

CROSS-OFFICE TEST TABLE 7654-B

This table provides facilities to test the LARP (cross-office reperforator), the loop-gate transmitter, the automatic numbering machine, the sequence number indicator. and Character Check Switch 7584-A. As the electronic units used in



Cross-Office Test Table 7654-B

Plan 55 cross-office transmission are also used on this table to complete the test circuits for the above-mentioned equipment partial testing of these electronic units is possible also. All of the tests provided by this table are dynamic in nature and therefore very effective

With a test tape consisting of the characters ZCZCZC LineFeed NNNN repeated continuously, a complete test of the character check switch, the LARP (both punching and read-back contacts), and the cross-office transmission reliability of the loop-gate transmitter can be automatically conducted. In making this test, the LARP regenerates the test tape for the loop-gate transmitter. The sound produced by the stepping of the character check switch is very rhythmical and a wrong character punched in the tape or a failure of the character check circuit will produce an easily detected discord in the rhythm. This allows testing of a very thorough nature with relatively little attention to the test being needed.

More Thorough Checking

To check completely the loop-gate transmitter, a different test is required, but it is entirely automatic and therefore can be unattended. The test tape used consists of the characters LineFeed NNNN CarriageReturn Space repeated continuously with extra character blocks of varying length inserted between the last N and CarriageReturn and between Space and LineFeed. This tape is then regenerated by the LARP when it passes through the loop-gate transmitter to produce an endless test. The LineFeed NNNN combination moves the loop-gate transmitter shuttle to the left-hand position and CarriageReturn moves it back to the normal right-hand position. The LARP does not copy what the loop-gate transmitter reads while the shuttle is in the left-hand position. The Space will provide an auto stop in case the test tape is not read correctly, or in case of a character loss when the shuttle shifts from one position to the other.

Tests on the operation of the automatic numbering machine or of the sequence number indicator require more maintenance time as the tape generated by the test must be visually scanned to determine if any errors exist. By operating the appropriate switches, either the numbering machine or the SNI is used as a transmitter to produce tape in the LARP. This arrangement will allow continuous transmission of the character sequence wired into the numbering machine or the SNI. Examination of the tape produced will determine any error in the machine being tested even though the error occurs on just one certain number combination.

In addition to the extensive tests already mentioned, this table has a special circuit (available by setting the right switches) to permit stroboscope tests on the "closed interval" of the LARP read-back contacts.

LINE TEST TABLE 7652-B

This test table, in conjunction with Equipment Rack 7672-A, provides dynamic testing facilities for the LBXD, LPR, message waiting control bank, sending control chassis, and the multipoint control chassis. The test table circuitry is almost identical to the actual Plan 55 incoming and outgoing line circuits.

The LBXD output circuit and the LPR input circuit are passed through a jack panel to provide a means of checking the signal bias and distortion, stroboscope testing of the LBXD, or for patching this equipment to some other circuit. Extra jacks are available to terminate two remote circuits within the table. To further increase the versatility, sources of battery, ground, and so forth, are also available on

Line Test Table 7652-B and Equipment Rack 7672-A

jacks. This allows the maintainer to "patch up" a number of special circuit arrangements as the need for them arises. In addition to testing the normal functions of the incoming and outgoing line equipment, a special circuit is provided to permit a stroboscope test of the LPR readback probe and common contacts.

To test the LPR and the message waiting control bank, read-out lamps are available to indicate proper operation of each output of these two units. A push button is provided to activate the tape feedout circuit. Correct printing and perforating is checked by feeding a test tape to the LBXD which then generates the signals to activate the LPR selector assembly.

The LPR read-back contacts and the message waiting control bank circuits can be tested by using a tape consisting of the characters ZCZC, short test message, FigureShift, four bells (upper case S), LineFeed NN LineFeed NNN LineFeed NNNN. The incomplete end-of-message functions are used in order to test the reset circuits of the message waiting control bank as well as to give a more reliable indication of the condition of the read-back contacts. Correct read-back will prevent operation of the no-end-of-message readout lamp. To determine whether false operation occurs on the partial end-of-message functions, it is necessary to observe the end-of-message relay in the message waiting control bank. The figureshift four-bell signal combination, when read on the LPR read-back contacts and properly stored in the message waiting control bank, will activate the "priority" light on the test table.

Sending Control Chassis Test

To test the sending control chassis, a tape consisting of ZCZC, short test message, LineFeed NNNN, followed by a number of blanks is placed in the LBXD. If the sending control chassis is operating correctly, the LPR will reproduce the test tape without error except for the omission of the blanks separating the test messages. Failure to omit the blanks indicates a failure of the sending control chassis end-of-message reading circuits. The extra end-of-message functions of the sending control chassis can also be checked at this time as the LPR will copy whatever the sending control chassis puts out on the line following the end of the test message. These added characters are controlled by a switch on the sending control chassis.

To test the multipoint control chassis, a test tape consisting of ZCZCX, short test message, LineFeed NNNN, ZCZCY, short test message, LineFeed NNNN, ZCZCZ, short test message, LineFeed NNNN, is placed in the LBXD. The characters ZCZCX, Y or Z are then read by the character reader which causes the multipoint control chassis to initiate the proper cycling functions to select the appropriate outstation. These cycling functions will appear in the tape on the LPR allowing one to determine their correctness. One must manually initiate the cycling to determine its correctness for selecting a drop to send to the switching center.

TEST TABLE 9414-A

This test table is designed to check the operation and the reliability of the following electronic units: Electronic Receiver 7545-B, Pulse Generator 7563-B, Electronic Transmitter 7564-B, and Electronic Transmitter 7615-B. The table is arranged to provide dynamic tests, using the loop-gate transmitter as a signal source, of all circuits associated with cross-office character transmission, and static tests of the remaining circuits of the above-listed units. A clever switching arrangement is used to provide for testing the ZC, CarriageReturn, Space, and LineFeed NNNN read circuits in Electronic Transmitter 7615-B, and also to test the CarriageReturn, Space, and LineFeed NNNN read circuits of Electronic Transmitter 7564-B. With the switches properly set up, a ZC, CarriageReturn, or Space passing over the loop-gate transmitter pins will activate the loop-gate shuttle as a read-out indicator causing it to move to its left-hand position. In this position, a LineFeed NNNN combination will cause

the shuttle to return to its normal right-hand position.

A test tape, consisting alternately of a character to cause the shuttle to move to the left, and then one to move it back to the right, should be used. Visual observation of the shuttle shifting back and forth will show up any failure of the character reading circuits in the electronic transmitter being tested. To test the cross-office transmission ability of either electronic transmitter requires only that the tape produced by the LARP correspond character by character with the test tape in the loop-gate transmitter. A switch is provided to allow any one of the four possible electronic transmitter line circuits to be used for simulating a normal cross-office circuit.

Checking Control Pulses

A means of checking the generation, transmission, and reception of all control pulses (7th, 8th, and 10th) is provided through switches to activate each circuit. Neon read-out indicators determine the results of the tests. In conjunction with these tests, additional switching is included to allow testing of the electronic transmitter trouble detection circuits. Very extensive testing of the LARP read-backs is possible with an additional piece of equipment (Auxiliary Reperforator Mounting 9425-A and an additional LARP). A test tape is fed to the loop gate which transmits to the normal table reperforator, the read-back contacts on the table reperforator are connected to the auxiliary reperforator which produces a tape that corresponds to the read-out characters. Even a very intermittent failure of the tape reperforator read-back contacts can thus be detected.

It is possible, when making any tests on the electronic units, to vary the bias voltage on the tubes thus establishing the "margin" existing in the unit and giving some indication of the life that can be expected before failure of the unit occurs.

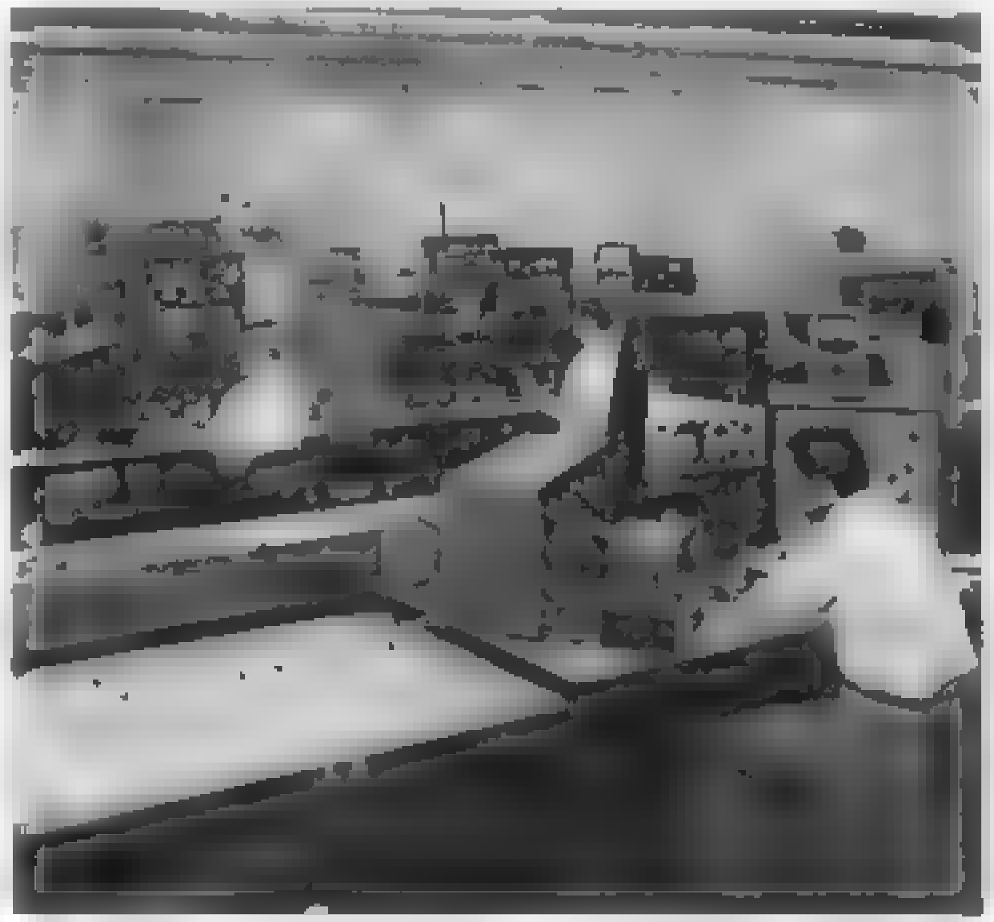
* * * * *

Many elements of Plan 55 can be partially to completely tested on more than one of these test tables. Many more test arrangements are possible than have been included in this article. The test tables are, in fact, so versatile that their use is limited more by the ingenuity of the operator than by the tables themselves.

RICHARD L. EMERSON graduated from Washington State College in 1954 with a B.S. degree in Electrical Engineering, after having twice interrupted his studies to serve in the Air Force in the European Theatre and elsewhere. He joined Western Union as a field engineer in the Oakland area in 1954, and became associated with the Plan 55 program in 1956. During 1957 Mr. Emerson instructed Air Force maintainers in the operation and maintenance of the system and since 1958 has been Project Supervisor for the Plan 55 center at McClellan Air Force Base in Sacramento, Calif.

Technical Associates of Western Union — II
Hermes Electronics Co.

UNIQUE in the electronics industry for a number of reasons. Hermes Electronics Co. has a fine competence in communications systems engineering. When the company was organized in May 1955 it was the first private organization to offer consulting services in the field of tropospheric scatter communications. It has done the systems design for the "Ace High" communications network in Europe, a combination tropospheric scatter and line-of-sight system which extends more than 5000 miles and links virtually all of the NATO countries from northern Norway to the eastern part of Turkey near the Soviet border. Hermes also designed the telecommunications system for the United Kingdom of Libya, and recently signed an agreement with Marconi's Wireless Telegraph Company, Ltd., of England, which provides for general technical collaboration between the two companies in the field of point-to-point communications.



This photograph illustrates test and calibration area in the crystal filter division of Hermes Electronics. Hermes dominates the market for these filters and backlog is now at record levels for this patented product

"Another unique feature of Hermes Electronics Co.," says its President M. M Hubbard, "is its cross-fertilization policy between research and development work and product work. We consider that we have maintained an excellent balance in these areas, and that commercial products which we manufacture are frequently by-products of our engineering activities. We are the largest manufacturer of high-frequency crystal filters in the world Other products which we manufacture include digital timing equipment, tape search equipment, and ultrastable oscillators which vary less than five parts in ten billion parts per day." A product to be introduced shortly is a digital language translator which will translate from any binary code into a decimal readout, for the computer industry.

A third feature which makes Hermes unique is its Technical Advisory Board. This board is composed of a group of well-known scientists (among whom are two Nobel laureates) and performs two important functions. First, it brings an academic attitude into the industrial environment, thus providing information on new areas for Hermes to explore. Its second function is to provide consulting services on various company problems and to examine current research programs.

Originally, because of a close association with Hycon Manufacturing Co., of Pasadena, Calif., the Hermes company was named Hycon Eastern, Inc. Its headquarters are at Cambridge, Mass. Western Union owns a stock interest in the company

W. DAIL CANNON, Assistant to Transmission Engineer

T. FRED COFER, Senior Project Engineer, Transmission

Layout and Adjustment of a Nationwide Facsimile Network for Weathermap Service

Much has been said about both envelope delay measurement and delay distortion correction. Successful application of the recently developed techniques discussed here is summed up rather concisely in the comment that "There was practically no difficulty in meeting the delay equalization standard of plus or minus 250 microseconds range between 900 and 2800 cps, most of the sections coming out better than this."

WHEN THE U. S. Air Force approached a Western Union representative in Washington, D. C., in June of 1957 with regard to increasing the speed and coverage of the facsimile weathermap circuits already in service, the Telegraph Company was prepared to do the job. Western Union not only already had an extensive installation of some 36,000 Desk-Fax® facsimile circuits for telegram delivery purposes, but also had a smaller number of circuits leased to private customers in various parts of the country. While most of these were short intracity circuits, some were longer; the Air Force in particular was using three circuits radiating from Omaha, Nebraska, to all three coasts, for conventional letter-sized copy. In addition, a weathermap recorder had been developed for the Navy Department, although it was not put into quantity production.

General Transmission Considerations

Experience in setting up the longer circuits had brought out the importance of envelope delay correction for the facsimile signals, a task which could be performed readily by especially trained engineers using delay-measuring and correcting devices developed in the Western Union transmission research division. An active type adjustable delay equalizer had given satisfactory performance in field trials, although the latter also had not been put into quantity production. Experimental work had indicated a way to increase the speed of facsimile transmission over available voice-frequency facilities by the use of vestigial sideband transmission although few circuits were yet in service. Given some time for further development work, Western Union was convinced it could provide the necessary apparatus and the adjusting equipment for the proposed network.

The first conference on the desired program for installations rapidly dispelled these ideas. There was insufficient time to carry development much further, hence it was necessary to proceed on the basis of purchasing weathermap transmitters and recorders, either already in production or well along in development, elsewhere. Since the line facilities would mostly be leased from the Bell System and associated companies, the project, as envisaged would leave Western Union responsible mainly for the initial line-up and the subsequent maintenance of the facsimile equipment together with the line-transmission aids and appurtenances. Because Western Union has the only completely nationwide communications field maintenance force, reporting to one central headquarters, in the continental United States, the scheme as finally proposed appeared logical.

Inspection of the equipment locations and desired circuit connection showed that the proposed weathermap service actually required four separate networks.

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., February 1960

From each of three command bases, one each on the Atlantic, Pacific and Gulf Coasts, circuits radiated to the satellite fields of those commands so that special data could be transmitted to their own groups. A fourth network comprised a "backbone" feeder circuit from Weather Headquarters near Washington, D. C., and from SAC Headquarters in mid-continent to each of the three command bases, so that national and worldwide maps or other information could be disseminated to all the connected fields. A number of subsidiary locations, not satellites of the three main bases, were to be attached to the fourth network. In addition, facilities for permitting each of the three main bases to transmit over the entire network, under control of SAC Headquarters, were desired.

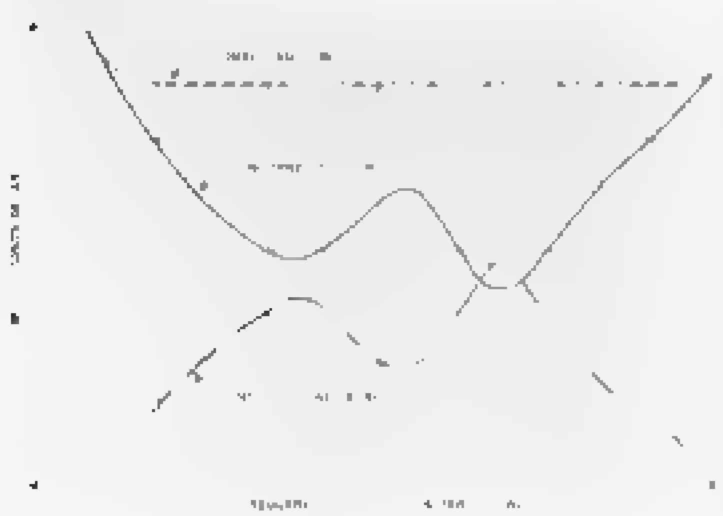


Figure 1. Random circuit characteristic

In an arrangement such as that proposed it was patent that use of the shortest circuit to each field would not be practical and that a number of air fields would need to be connected along each of the various circuits. It seemed probable, therefore, that an unusually large number of carrier line sections in series would be required to reach the remote stations. In such a system, in general, amplitude distortion can be corrected by the usual simple methods. Delay distortion inserted by each pair of voiceband terminals, however, will grow progressively worse unless it is especially corrected at intervals of a few sections. In addition, the physical loops between carrier terminals and the recorder drop positions often add considerable amplitude and delay distortion.

Although the vestigial sideband transmission projected for the system could compress the required signals into about 2000 cycles of spectrum instead of the more than 3000 needed for double-sideband operation, it was not known how many carrier line sections in series could be tolerated. The critical envelope delay distortion at the edges of the transmission band increases almost linearly with the addition of like carrier sections in series, the primary contributor being the filters in the frequency-translation equipment. Although such delay distortion cannot be subtracted from the circuit, it can be "equalized" over the desired transmission band by adding delay in the right places. (See Figure 1.)

The first problem, then, was to determine if the long links needed in the network were feasible. Tests with a transmitter and recorder loaned by the proposed supplier of such equipment were therefore performed. As indicated in Figure 2, at the desired speed of 120 scans per minute, the recordings over various numbers of line sections did not show serious depreciation in resolution when compared to "back-to-back" operation, provided the line sections were properly equalized. A tentative standard for equalizing was then drawn up suggesting that the maximum number of sections in any branch be limited to 15, that no more than five sections be corrected with one delay equalizer, and that a separate amplitude equalizer be used to correct nonloaded cable loops to the apparatus locations. Range standards were ±250 microseconds and ±2 decibels over a band from 900 to 2800 cps.

During the preliminary tests, the RJ-3 Recorder manufactured by the Westrex Corporation (formerly Times Facsimile), available in quantity and similar to those already in use on the existing weathermap circuit, was found to operate perfectly satisfactorily at the increased speed required and with the type of vestigial sideband operation proposed for transmission over the new circuit. A special large transmitter, the CL-2, about to go into produc-

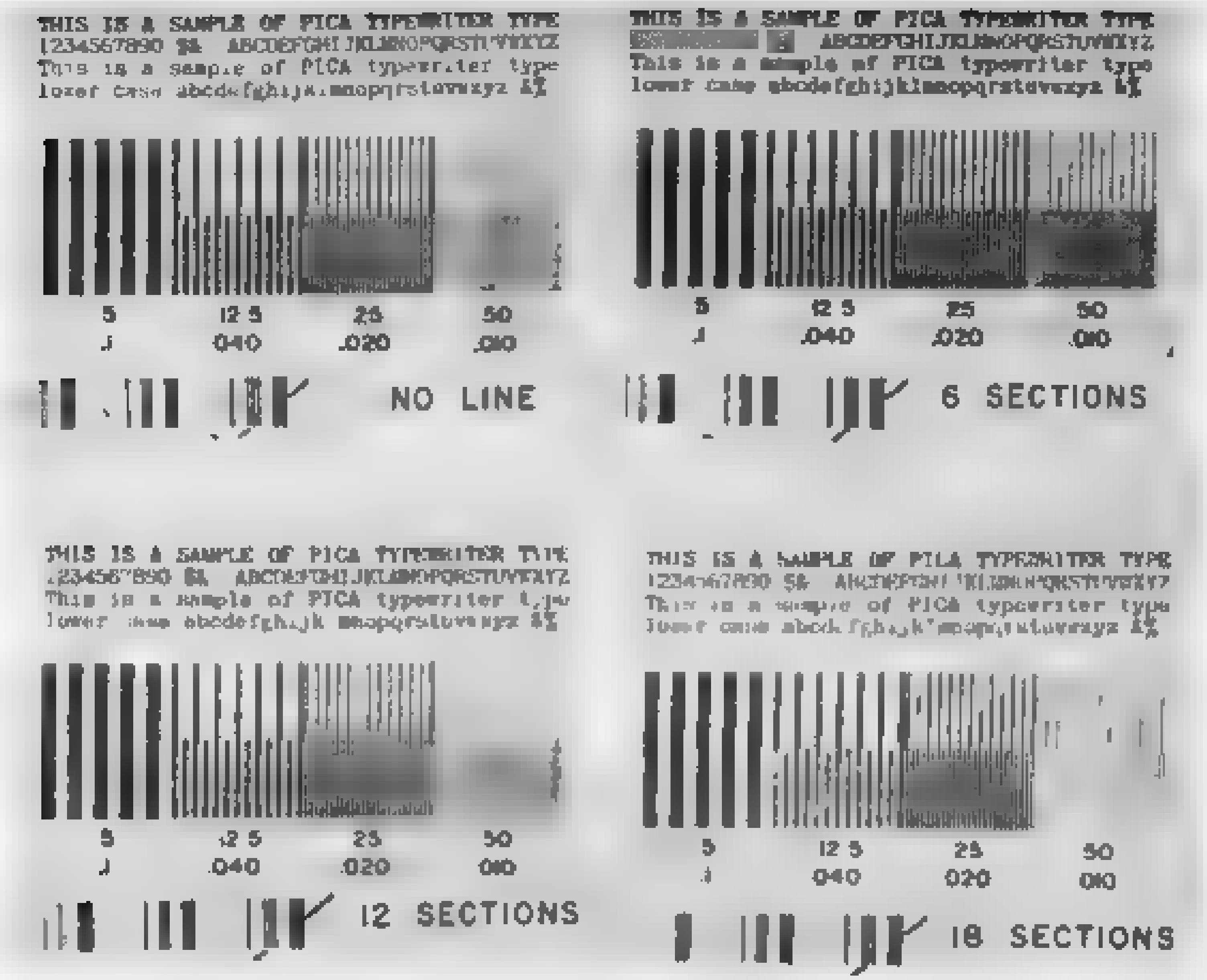


Photo R 11 687

Figure 2. Preliminary test copy — examples of test results May 16, 1958

tion by Westrex, was to be available in both single and dual mountings and otherwise met the requirements specified by the Air Force. These two important terminal equipments, shown in Figures 3 and 4, were therefore ordered for use in the new weathermap service. A discussion of the vestigial sideband transmission arrangements selected for the service is in Appendix I.

In order to simplify routine adjustments of the facsimile transmitting equipment, it was decided to associate the vestigial sideband filters directly with the transmitters themselves rather than with the lines. The manufacturer cooperated in this arrangement by providing space on the chassis and a multiconductor plug for adding the vestigial unit to the transmitter circuit. Although this location increased the number of units required, the total number of transmitters is small compared to the number of recorders. Because the recorders are generally located at the ends of cable loops connecting to the main-line circuit, small simple amplitude equalizers were designed to fit in the recorder cases. These, in cooperation with the delay equalizers ordinarily located in the nearest Western Union office, provided the line-correcting devices to be adjusted.

Test Equipment

The correction of envelope delay distortion at specific intervals so that this distortion does not accumulate in excess of a specified minimum at any recorder position requires an elaborate system of delay measurement and correction techniques. Envelope delay measurement is most conveniently accomplished by means of the Envelope Delay Measuring Instrument, an early form being arranged as described

in reference 1. Delay distortion correction can most readily be accomplished by means of an active type of equalizer operating on principles described in reference 2. The active type of equalizer is preferable to the passive type because it is continuously adjustable, thus being more practical than the passive type, in the usual form of fixed step equalizers, for compensation, in the field, of delay distortion accumulated over a series of voice-band circuits, local loops, and the inherent mismatches of circuit parameters.

Photo M 4060 4

Figure 3. Weatherfax Recorder RJ-3

Photo R-11,74

Figure 4. Weatherfax Transmitter CL-2

Considering the large area of the country to be covered in the line-up procedures and the necessity for the regular field maintenance forces to support circuit operations after start-up, it seemed desirable to use the field forces to do the initial transmission work rather than to send out teams from the laboratory or general headquarters. Some of the field engineers were already familiar with delay measurement and correction with the older equipment, but the original delay-measuring instrument, satisfactory for many purposes, particularly in the laboratory, needed several improvements if it was to be put into general field use. These improvements with respect to stability, sensitivity, and method of indicating delay values are especially desirable to make operation in the field as simple as possible.

The delay-measuring instrument operates by comparing the time relationship between two sets of pulses at the receiver One set, used as the standard of reference, is derived from a local precision tuning fork oscillator at the receiver. The other set is derived from the 25-cycle envelope of a modulated carrier that has been transmitted over the circuit whose characteristics are to be measured. The 25-cycle modulating frequency is derived from a similar precision tuning-fork oscillator at the transmitter. While these two oscillators need not be exactly synchronized, the drift between them should be very small so that delay information can be obtained with ease and precision particularly in the case of field applications where the ends of the circuit are far apart. In the measuring instruments especially designed for field use new oscillators have been provided that can be adjusted readily so that the change in observation caused by their drift does not exceed a few microseconds per minute, a short-time stability more than adequate to obtain accurate delay readings. This accuracy of the oscillators is associated with an improved tuning-fork driving circuit of the impulse type which allows the fork to operate in its natural mode as a free unit over practically the whole cycle except for a small impulse period. Further details of the method of deriving envelope delay information from a modulated wave are given in Appendix II

Ease of obtaining delay readings has been further improved by making these readings depend upon the precision oscillator frequency rather than upon a set of

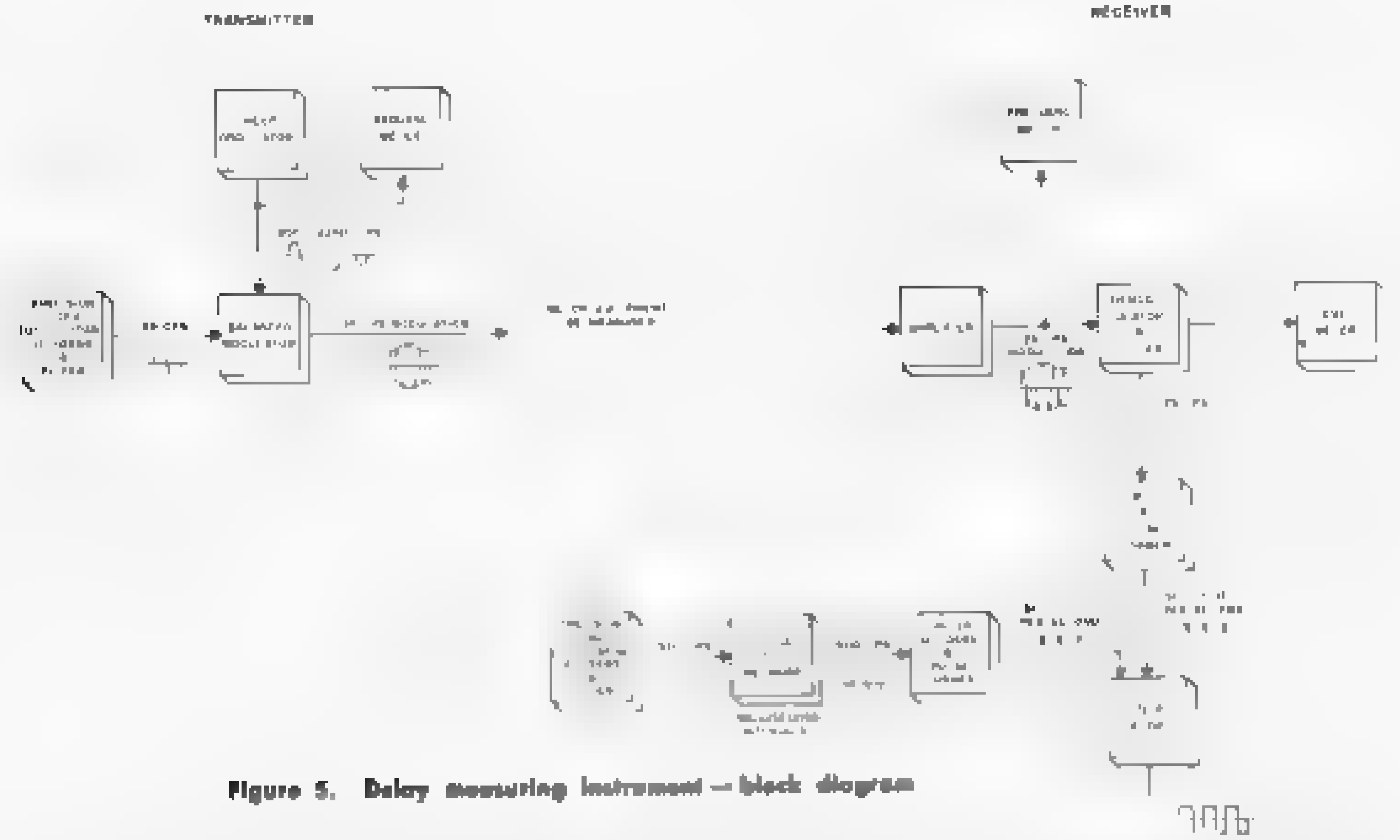


Figure 5. Delay measuring instrument — block diagram

calibrated scales as in the older type of instrument. By this means, readings of delay can be obtained which approach the accuracy of the oscillator itself. This is accomplished by phase-shifting through a fixed number of cycles of the oscillator frequency for each one-millisecond "cardinal" point to establish a continuous range of one-millisecond intervals. A meter of one-millisecond full scale is used to interpolate between cardinal points with an error not exceeding about five microseconds. Thus the sensitivity has been increased by a factor of five over the older instrument, overlapping scales requiring frequent checking of calibration are avoided, and simplicity in reading the delay values has been accomplished. A block diagram of the new design is shown in Figure 5.

The early type of active equalizer was designed on the basis of electron tubes and was not intended to be used for permanent installation in the field. This corrective network has been improved to provide an equalizer eminently suitable for field use. The new delay equalizer consists of six transistorized active sections, an output stage and an associated power supply. A schematic drawing is shown in Figure 6 and a photograph in Figure 7. The input from the line passes through a gain-adjusting H-pad and an essentially one-to-one input transformer to the emitter circuit of the first stage. One of the properties of the transistors as they are used in this equipment is that the

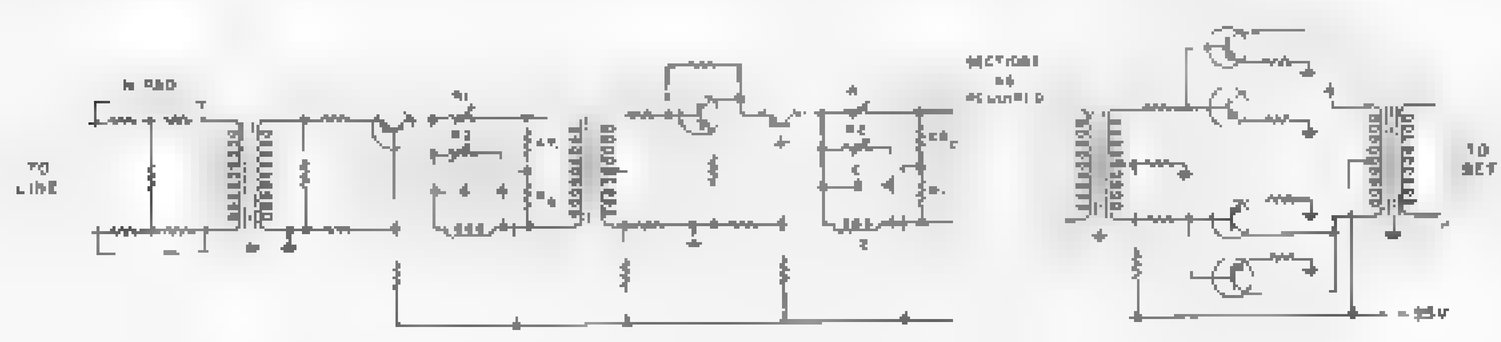


Figure 6. Delay equalizer — schematic

input impedance is low and the output impedance is comparatively high. As a result, the output impedance of the two series-cascaded transistors, used in all stages except the first, is very high. It is necessary, therefore, that the delay networks be suitable for operating from a

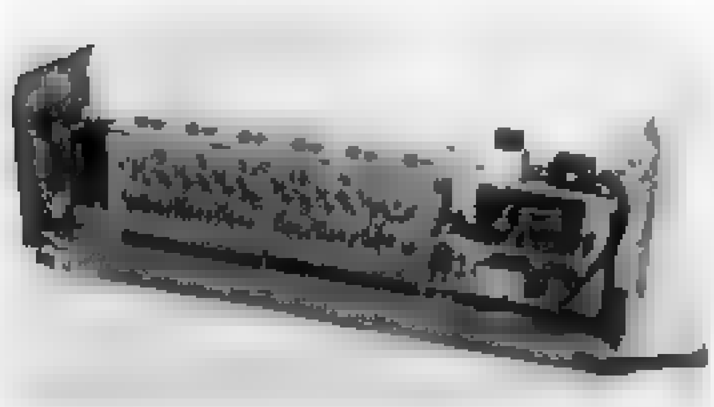


Photo R 11,631

Figure 7 Delay Equalizer 9553-A

constant current source into the comparatively low-input impedance of the transistors. The single transistor used in the first stage thus causes a lower level than that on the line to appear in the following stages to preclude overloading of the network transistors in case abnormally high levels are applied to the line. For H-pads of two decibels loss or higher, the input transformer and first stage emitter have overload characteristics that guard the equalizer itself from permanent damage for any lightning or power induction surges that normally can pass by the office protectors.

The signal then progresses through the remaining five sections at a uniform level or with a small increase in level from stage to stage. The output from the last section is applied to a push-pull output amplifier. The output amplifier restores the level to that of the original input level. Considerable negative feedback is included in the six sections to assist in stabilizing the gain.

The delay and amplitude characteristics are varied by adjusting two resistors in each section. If these resistors are maintained equal, the delay characteristic will be dependent upon their common value while the amplitude characteristic will remain constant for all settings. The equipment also can be adjusted to produce a variable amplitude characteristic by offsetting one resistor with respect to the other. With this equipment, therefore, it is possible to adjust the delay characteristic over a wide range and the amplitude

Figure 8. Connections for testing

characteristic over a somewhat restricted range essentially independent of each other, by varying only the two resistors in each section. A mathematical analysis of the operation of the equalizer is given in Appendix III

A special adjustable resistance box is ordinarily used during tests to establish the proper values of the section resistors. A setup of the delay measuring set, equalizer and the adjustable resistance box is shown in Figure 8. Adjustment of the resistance box, section by section, is made until the delay measuring instrument indicates that the summation of the delay added by each individual section, together with the associated amplitude changes, provides a satisfactory correction of both delay and amplitude distortion. Fixed resistors of values determined from the settings of the adjustable resistance box are then soldered in place at the terminals provided in the equalizer to make a permanent installation

Transmission Network Adjustments

Line transmission facilities for the circuits eventually set up for the weather-map network were ordered in four categories: 1. The "backbone" feeder circuits, which are mostly duplex or two-way circuits connecting the five possible transmission points together; 2. The circuits associated with the 8th AF radiating from Westover AFB, Massachusetts; 3. Circuits radiating from 2nd AF Headquarters at Barksdale AFB, Louisiana; 4. Circuits radiating from 15th AF Headquarters, March AFB, California. The circuits were required to be ready at intervals of one month, starting January 15, 1959 with the feeder network. In the early part of January, schools for the field engineers, lasting about three days, were held in New York City and Kansas City. Meanwhile delay equalizers, level amplifiers, and other equipment units were installed in the locations required on the same schedule as the circuit requests.

With six measuring instruments available, the general plan was to locate one set in the central point at Omaha, Nebraska, and equalize all the connecting lines from or to that point. Because of changes and additions to the circuits after starting service it was found impracticable to perform all the equalizing tests from Omaha, but most of the remaining tests were made either from one of the three AF Headquarters or, where necessary, from one of the important "VIA" points along the system. There was practically no difficulty in meeting the delay equalization standard of plus or minus 250 microseconds range

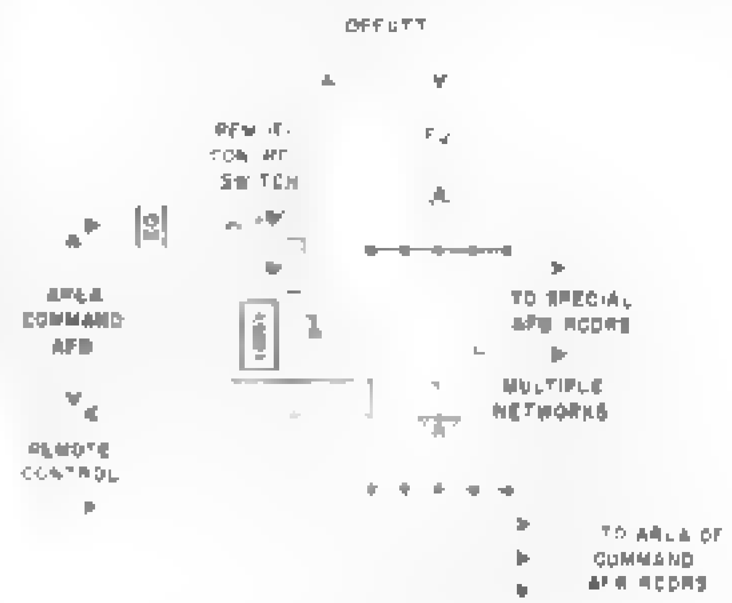


Figure 9. Switching for three command bases

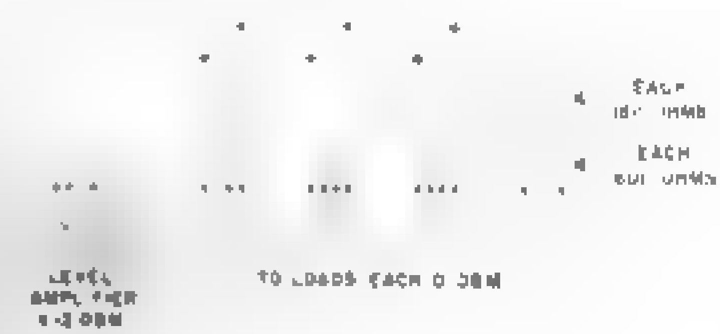


Figure 10. Details of multiple network

between 900 and 2800 cps, most of the sections coming out better than this. While the total number of line sections in the longest loop is believed to be not more than fifteen, no extensive effort was made to determine the exact number since it was realized that rerouting in emergencies may alter the arrangements anyway. Based on tests it is believed that a change of plus or minus two line carrier sections in any long branch can make very little difference in the copy, and perhaps plus or minus three line carrier sections can be tolerated in the longer loops.

The switching requirements of the system posed some small problems. At each of five locations it was necessary to provide switching to permit the several transmitters to function as required. The general arrangements were the same at each of the three AF field headquarters of Westover, Barksdale and March Fields. Figure 9 indicates how the local transmitter can be switched either to the local area circuits or to the trunk to Offutt AFB, and Figure 10 shows the details of the multiple network. The local area circuits, when not connected to the local transmitter, are switched to the main network. The switching at Offutt AFB, Figure 11, can connect its local transmitter or those at the other points to the main network. Note that both Suitland and Westover use the same trunk into Omaha. Figure 12 shows how this arrangement is accomplished, the transmitting trunk from Westover being bridged on the Suitland transmitting circuit. Note that both Suitland and Westover receive copy from Omaha, adding extra circuit length to such transmission. This arrangement is necessary to permit Offutt AFB to control the connections to the main network. No difficulty has been encountered in operating the system in this manner.

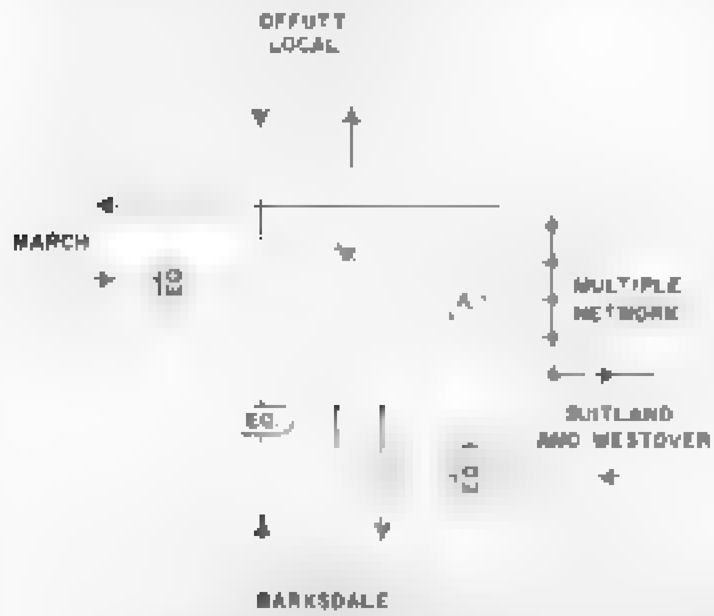


Figure 11 Switching at Offutt AFB

The excellence of the equalization obtained, and the step-by-step method of measurement along a branch line which tends to "mop-up" correction errors so they do not pile up at the ends, is illustrated in Figure 13. An example of one type of weathermap as transmitted over the circuit is shown in Figure 14.

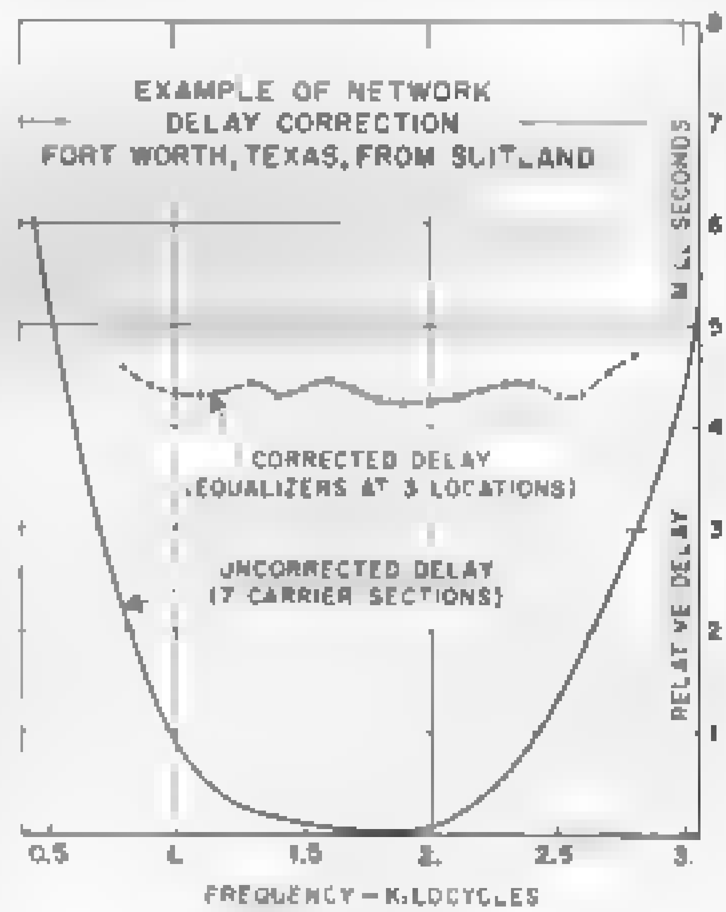


Figure 13. Example of equalization

* * * * *

The field maintenance forces did a very good job in coordinating the transmission over some 20,000 circuit miles of transmission facilities. Much praise also should go to the testing equipment which, although quite complex, survived a great deal of travel by various means without any serious damage to the components.

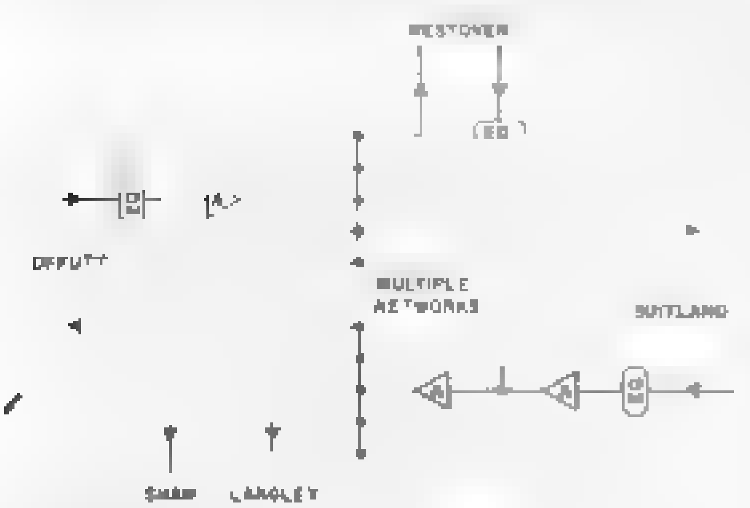


Figure 12. Connections at Washington, D. C., Western Union office

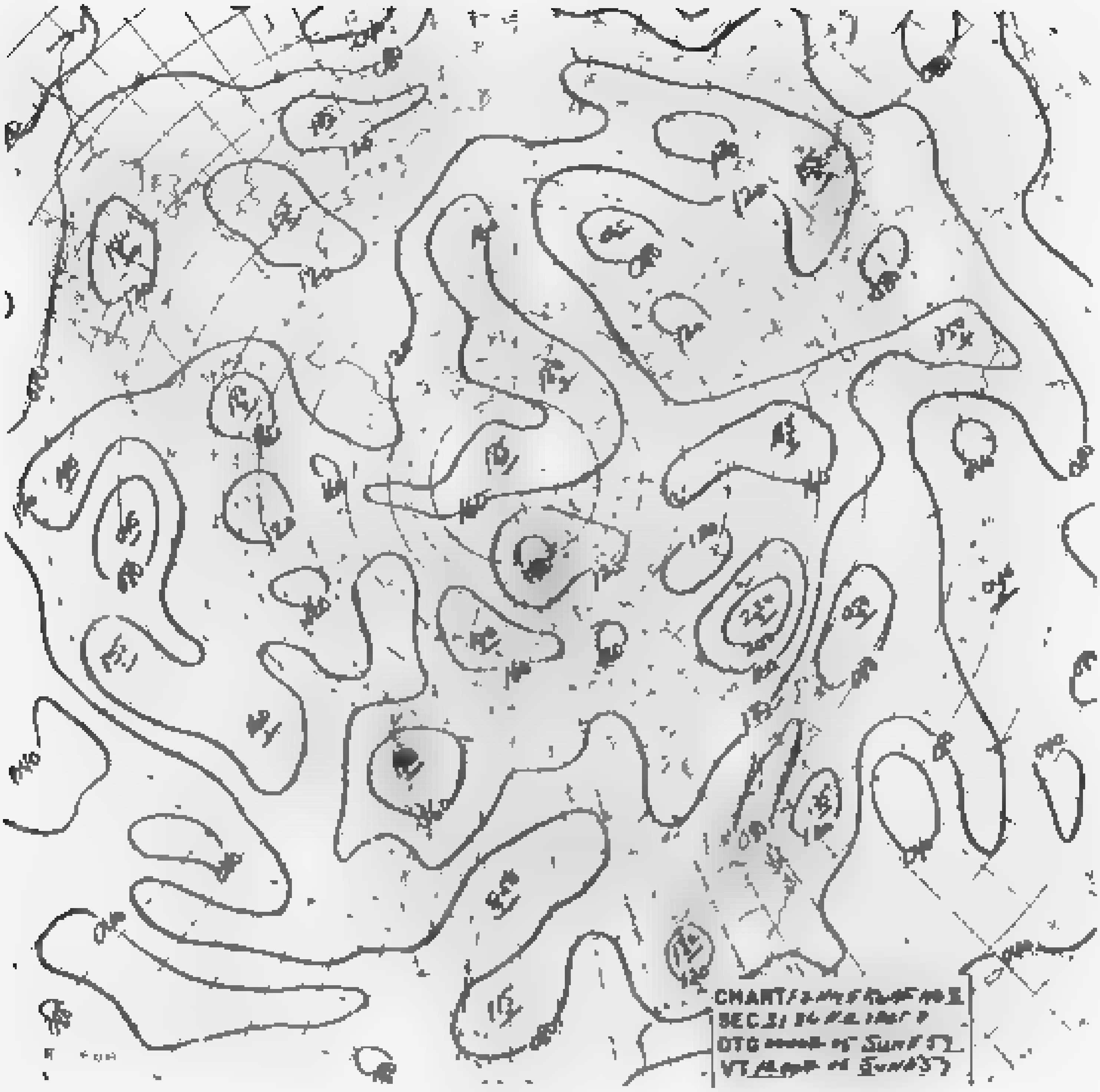


Figure 14. Example of recorded weathermap

APPENDIX I

Design Criteria for Vestigial Sideband Filters

The original weathermap network operated at 60 scans per minute, about 18.5 linear inches per second, which at a resolution of 96 lines per inch required approximately 900 cps of modulation. Even with double-sideband modulation, the resulting 1800-cps bandwidth can be given satisfactory transmission over most of the available voicebands, with a carrier frequency between 1800 and 2000 cps. When the speed is doubled, however, to 120 scans per minute, the normal voiceband can no longer accept the double-sideband signal covering 3600 cps.

Because facsimile recording signals must extend from zero frequency, delineating large black areas, up to the maximum resolution desired, it is impracticable to use truly single-sideband transmission to reduce the required bandwidth, so some kind of modulation producing one sideband completely and a small part, or vestige, of the other sideband, is indicated. Such "vestigial sideband" systems have been examined quite thoroughly and their advantages and defects are well known, as are means of obtaining the best results

with this method of operation. (References 3, 4 and 5.)

For the weathermap system, a vestigial system sideband arrangement was chosen using the complete lower sideband with some 400 cps of the upper sideband, a nominal bandwidth of 2200 cps. Tests showed that a carrier located at 2400 cps produced the best results, requiring an upper frequency approaching 2800 cps, well within the capabilities of most commercial carrier systems. An active vestigial sideband filter, having a feedback circuit to improve the amplitude and delay characteristics over its counterpart passive network, was designed for these frequencies. The filter was planned for insertion in the transmitter circuits just ahead of the output amplifier so that the level and contrast settings could be made by normal procedures with the filter added.

Application of vestigial sideband principles of transmission introduces a signal distortion caused by the absence of the quadrature component of the missing sideband, the "carrier on" portion of the modulated signal being broadened. With conventional "carrier for black" transmission and normal high contrast ratio the presence of the quadrature distortion greatly thickens the single fine lines of the copy although it does less harm to the closely-spaced fine lines.

Arrangements have been devised for completely circumventing the quadrature distortion in transmission (references 4 and 5), but these require complicated equipment involving additional modulation at the recorder terminals. For instance, one such system consists in recovering the modulating signal at the receiver, remodulating another carrier, preferably of higher frequency, with an inverted signal and continuing through a second vestigial filter. The vestigial filter at the transmitter tends to broaden the fine lines while the second vestigial filter, because of the inverted signals, tends to narrow the lines, the process resulting in very low quadrature distortion. For positive recording, the signal after the second vestigial filter again must be inverted. Another such system involves the transmission of "carrier for white" signals through a single vestigial filter over the line to the receiver. This system tends to narrow fine lines of the copy, a factor which can be used to offset normal broadening of the lines due to the effects of the scanning aperture and recording stylus. Again, for positive recording, the received signals must be inverted.

Although quite useful for point-to-point circuits, such arrangements were considered unduly expensive for the weathermap network with its many far-flung recorders operating from a few transmitters. A more practical method of reducing the effect of vestigial sideband operation devolves from the fact that the quadrature distortion can be reduced to an unobjectionable value by employing appreciably less than 100-percent modulation of the carrier at the transmitter. For example, a reduction of the contrast ratio from 30 to 16 decibels will remove an appreciable part of the quadrature component. At the recorder it is necessary to furnish means of preventing the high continuous carrier level from marking the copy, but this can be done with a suitable blocking or bias voltage within the recording amplifier. The weathermap recorders are equipped with means for eliminating background marking from the continuous carrier level, and the transmitters are supplied with means for adjusting the contrast on the line side of the vestigial sideband filter to the required value. No difficulty has been experienced in maintaining these features of the transmission system since the early stages of system lineup.

APPENDIX II

Method of Measuring Envelope Delay

The operation of the delay measuring instrument is based upon the transmission of an amplitude-modulated wave comprising a carrier that has been modulated by a relatively low frequency. This carrier wave and the first order sideband frequencies after transmission contain the

necessary information for deriving the envelope delay properties at points in the frequency spectrum corresponding to the carrier frequency. A simple derivation is as follows.

For simplicity, assume that the three frequencies at any instant occupy such a narrow band of the spectrum that their relative amplitudes after transmission bear a constant relationship to each other. Let the transmitted wave be

$$V_1 = (1 + M \cos pt) \cos \omega t$$
$$= \cos \omega t + \frac{M}{2} \cos (\omega - p)t + \frac{M}{2} \cos (\omega + p)t$$

where

$\omega = 2\pi \times$ the carrier frequency

$p = 2\pi \times$ the modulating frequency

$M =$ modulation factor

In transmission, each of the three frequencies is shifted in phase by the phase properties of the circuit. Let the lower sideband frequency be shifted by β_1, the carrier by β_2 and the upper sideband frequency by β_3 in transmission. The received wave then is

$$V_2 = \cos(\omega t + \beta_2) + \frac{M}{2} \cos[(\omega - p)t + \beta_1] + \frac{M}{2} \cos[(\omega + p)t + \beta_3]$$

$$= \left[\cos \beta_2 + M \cos \left(pt + \frac{\beta_3 - \beta_1}{2}\right) \cos \frac{\beta_3 + \beta_1}{2} \right] \cos \omega t$$
$$\left[\sin \beta_2 + M \cos \left(pt + \frac{\beta_3 - \beta_1}{2}\right) \sin \frac{\beta_3 + \beta_1}{2} \right] \sin \omega t$$

The envelope of the received modulated wave then is

$$\sqrt{1 + 2M \cos\left(pt + \frac{\beta_3 - \beta_1}{2}\right) \cos\left(\beta_2 - \frac{\beta_3 + \beta_1}{2}\right) + M^2 \cos^2\left(pt + \frac{\beta_3 - \beta_1}{2}\right)}$$

As p is made decreasingly small as compared to

$$\omega, \beta_2 - \frac{\beta_3 + \beta_1}{2} \rightarrow 0$$

the radical becomes a perfect square and since $\beta_3 - \beta_1 = \triangle\beta$ and $2p = \triangle\omega$ the envelope becomes

$$1 + M \cos p\left(t + \frac{\Delta\beta}{\Delta\omega}\right) = 1 + M \cos p \left(t + \frac{d\beta}{d\omega}\right)$$

Thus the envelope of the received modulated wave has been shifted in time by the envelope delay properties of the circuit. Further, since the modulating frequency must be small as compared to ω there is a lower limit at which accurate results can be obtained. The lower limit occurs at a frequency where the carrier frequency is about ten times the modulating frequency.

APPENDIX III

Analysis of Active Network Method of Correction

It is possible to devise many types of active networks applicable to the correction of envelope delay distortion. A number of these are given in the article of reference 2 of which Group H in particular gives satisfactory performance in conjunction with the high-output impedance and the low-input impedance of transistors

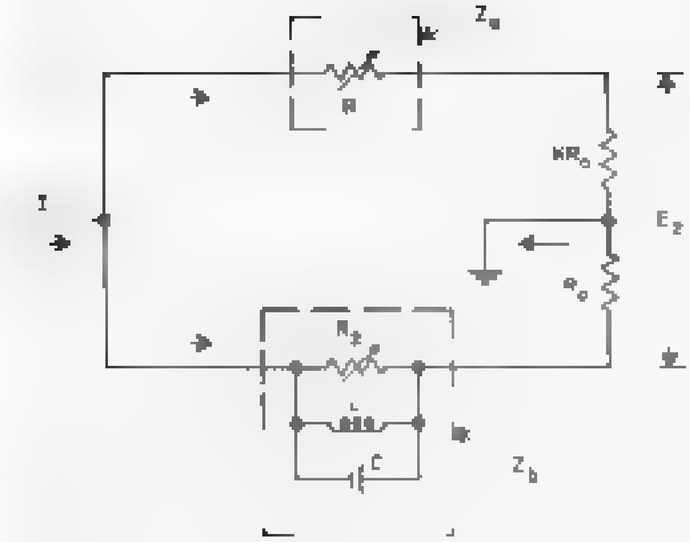


Figure 15. Active corrective network — schematic

used as the active elements. A schematic diagram of this arrangement is shown in Figure 15 in which

I = current from constant-current source

Z_a and Z_b = network configurations

K = a constant

R_o = resistance small compared to Z_a and Z_b

The transfer ratio of this arrangement is

$$\frac{E_2}{IR_o} = \frac{KZ_b - Z_a}{Z_b + Z_a} \qquad (1)$$

While several different network configurations may be chosen for Z_a and Z_b, the simple networks shown in Figure 15 have been found to be particularly useful for corrective purposes. The corresponding transfer ratio then is

$$\frac{E_2}{IZ_o} = \frac{jX(KR_2 - R_1) - R_1R_2}{jX(R_2 + R_1) + R_1R_2} \qquad (2)$$

where X is the reactance of L and C in parallel. In order for this arrangement to have all-pass properties, the factor K must conform to

$$K = 1 + \frac{2R_1}{R_2} = 3 \quad \text{for} \quad R_1 = R_2 = R \qquad (3)$$

whence

$$\frac{E_2}{IZ_o} = \frac{2jX - R}{2jX + R} = \angle\beta \qquad (4)$$

Equation (4) then has unity amplitude ratio and a phase shift

$$\beta = 2\tan^{-1}\frac{2X}{R} \qquad (5)$$

$$= 2\tan^{-1}\frac{2\omega L}{R(1-\omega^2 LC)} \qquad (6)$$

The corresponding envelope delay then is

$$\frac{d\beta}{d\omega} = -\frac{2RC(1+\omega^2 LC)}{\frac{R^2C}{2L}(1-\omega^2 LC)^2 + 2\omega^2 LC} \qquad (7)$$

For $\omega^2 LC = 1$ at which frequency approximately the peak delay of a section occurs, the delay is

$$\frac{d\beta}{d\omega} = -2RC \qquad (8)$$

Now, if R_2 is offset in value with respect to R_1 to produce an amplitude characteristic of nonuniform distribution with respect to frequency

$$\frac{E_2}{IR_o} = \frac{jX(3R_2 - R_1) - R_1R_2}{jX(R_2 + R_1) + R_1R_2} = A\angle\beta \qquad (9)$$

where

$$A = \text{amplitude ratio peaking at resonance}$$
$$\beta = \tan^{-1}\frac{2X}{R_a} + \tan^{-1}\frac{2X}{R_b} \qquad (10)$$

in which

$$R_a = \frac{2R_1R_2}{3R_2 - R_1} \quad \text{and} \quad R_b = \frac{2R_1R_2}{R_1 + R_2}$$

at resonance of L and C

$$A = \frac{3R_2 - R_1}{R_1 + R_2} = \frac{R_b}{R_a} \qquad (11)$$

and

$$\frac{d\beta}{d\omega} = -\left(\frac{2R_1R_2}{3R_2 - R_1} + \frac{2R_1R_2}{R_1 + R_2}\right)C = -(R_a + R_b)C \quad (12)$$

Hence the envelope delay introduced by the network is proportional to the difference between the currents in the two branches of the network on a 3-to-1 basis (Equations (3) to (7)) The 3-to-1 ratio is obtained by taking the voltage drops across R_a and KR_a so that E_2 represents the difference Both the delay and amplitude characteristics will be peaked at the resonant frequency established by the LC factor of each section. The delay always will be peaked upward at the resonant frequency while the amplitude may be either upward or downward for unequal values of R_1 and R_2. At the resonant frequency of a section, the delay which is approximately the peak value is equal to $-2RC$ and is independent of the value of inductor L. For this reason, capacitor C should remain constant from section to section and the LC factor to establish the position of the peak delay of a section should be determined by varying the inductor L.

The results as shown by equations (11) and (12) provide a very useful means of independently adjusting the delay and amplitude characteristics, since the delay is proportional to the sum of R_a and R_b and the amplitude is proportional to their ratio. The delay and amplitude characteristics are varied by adjusting resistors R_1 and R_2. Ordinarily the delay adjustment is made first, followed by the amplitude adjustment. In making the delay adjustment these resistors are maintained equal so that the amplitude ratio is fixed at unity and the delay is proportional to their common value. If in addition to the delay adjustment it is desirable to produce an amplitude ratio not having unity distribution with respect to frequency, it is usually sufficient to offset R_2 with respect to R_1 rather than maintain the relations of equations (11) and (12) for R_a and R_b. Over a limited range of offsetting of R_2, the delay will remain unchanged for all practical purposes. Such changes as do occur are confined essentially to the peak values. Thus, if $R_2 = 1.5\,R_1$ the peak amplitude will be increased to 1.4 but the peak delay will be increased by a factor of only 1.056.

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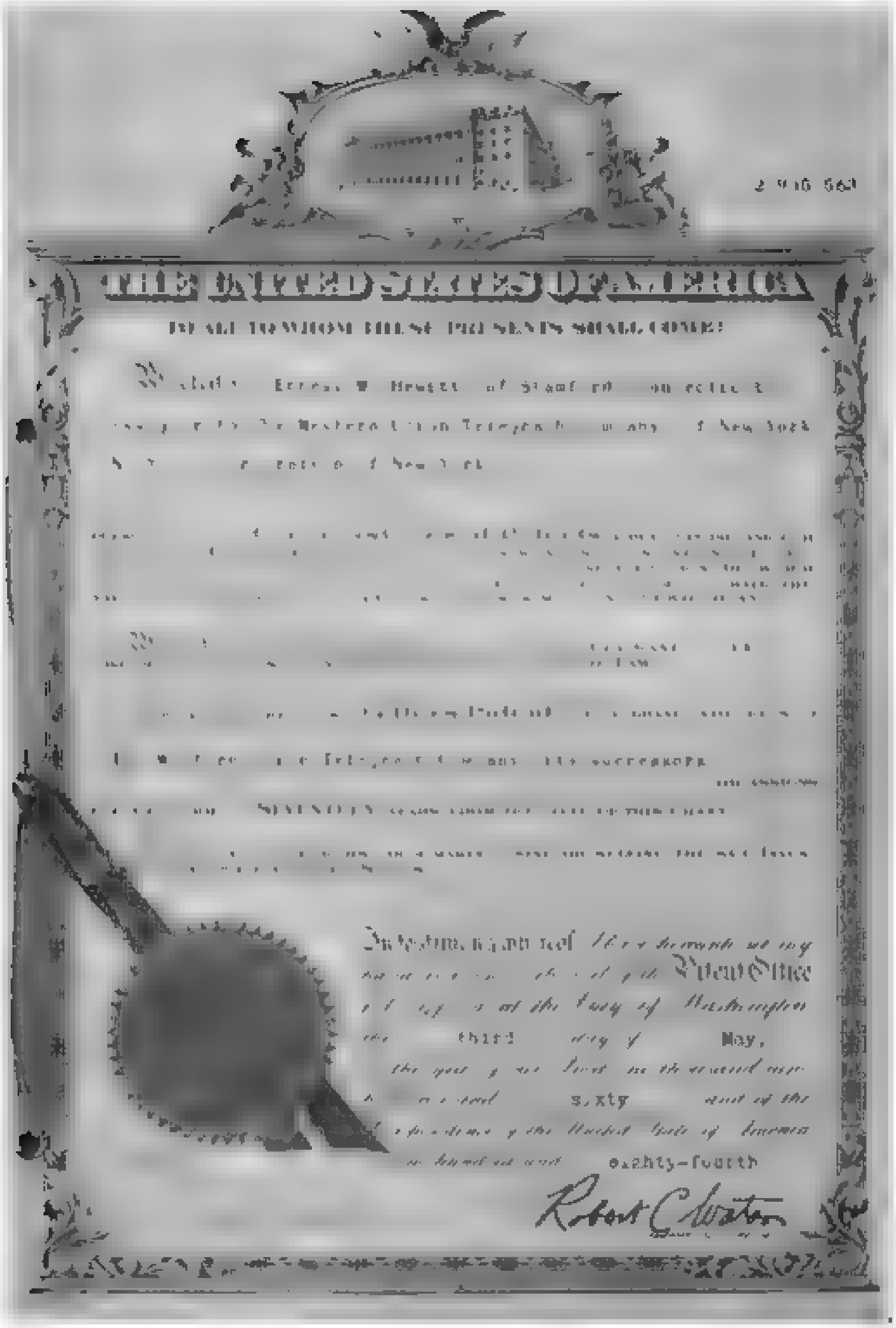
T Fred Cofer joined the Transmission Research Division of the Telegraph Company immediately after graduation from Virginia Polytechnic Institute in 1923. Except for a few years when he served as Assistant Consulting Engineer (1944) and Assistant Coordinating Engineer (1950-53), he has been primarily interested in transmission problems. At the present time he is a member of a team developing circuits and communications equipment for a proposed high-speed digital weather-reporting service. Mr Cofer is the author or co-author of numerous articles for Technical Review, and is a member of AIEE and Phi Kappa Phi.

W. DAIL CANNON, Assistant to the Transmission Engineer, received a B.S. degree from the University of Delaware in 1918 and in July of that year enlisted in the Signal Corps. After the war, he joined the Engineering Department of Western Union, but left shortly thereafter to attend the Graduate School of the University of Illinois, where an M.S. degree was awarded to him in 1921. Returning to the company, he engaged in theoretical and mathematical work on such projects as ocean cable transmission, correction of inductive disturbances, and electronic amplifiers. Mr. Cannon was responsible for the company's earth current neutralizing system and its power interference correcting method. More recently he has contributed ably to the deep sea repeater equipment, a simplified telegraph repeating relay, the development of instruments for the measurement of telegraph signal distortion, and methods for the measurement and correction of envelope delay distortion. In 1958, Mr. Cannon received the F. E. d'Humy Award for a most significant contribution to the telegraph art. He is a Fellow and member of the Board of Examiners of AIEE, and a member of Subcommittee No. 13 of ASA Committee on Definitions of Electrical Terms.

NEW AND THINNER ROUTE CHART LEAVES

Photo R 11,746

The new thin route chart leaves can be mounted approximately five to the inch, as compared to the older type which was so constructed that only two could be mounted to the inch. The two leaves at the left for 3-column sheets are Types 7355.1-A and 7355-A, those at the right for 1-column strips are Types 9234.1-A and 9234-A. The 7355.1-A and 9234.1-A leaves are identical with the 7355-A and 9234-A, respectively, except that the former have a series of holes in the upper outer frames which permit mounting Route Chart Tabs 8894-A in four different positions.



Formal title page of a recent U. S. patent is signed by the Commissioner of Patents and bound with ribbon and a red seal symbolic of a document in law. The Patent Office in Washington, D. C., is one of many divisions in the U. S. Department of Commerce in the building shown above in the masthead.

ROBERT H. HENDERSON, Patent Attorney

A Patent Refresher

Patent Office regulations are set forth in a booklet entitled "Rules of Practice of the United States Patent Office in Patent Cases." Although the Rules of Practice have a long history, going back to pamphlets of general information to the public first issued in 1856, there is much more that has not been recorded officially.

LITTLE THOUGH it may attract engineers and scientists, the dry subject of patents is one of importance to them. In fact, the more active and dedicated to technological matters such a man may be, the more directly and the more frequently he is likely to encounter the effect of patents. It is as well, therefore, for an engineer to renew his familiarity with patents as it is for him to retain his acquaintance with thermodynamics. A failure to do so is sometimes most costly.

A Legal Umbrella

In our economy of private free enterprise, it is a major role of the patent to make that progress which accompanies technological innovation commercially feasible, by enticing venture capital into the expensive fields of development, research, and production plant capitalization. This it accomplishes by holding out the promise of a market for the patented product or method, sheltered by a legal umbrella of exclusiveness for 17 years from all those eager competitors who would otherwise freeload by copying the product, free of the patentee's development costs, for sale at a lower price than the patentee could afford because of his costs and, of course, with the total loss to the patentee of his venture capital.

It is upon this promise that many enterprises are based, and it provides practically the sole entrée for a small new business in a highly competitive field. Many an engineer owes the existence of his chosen technological field to the patents which have made the cost of its development an attractive speculation.

This view of the patent—as being a basis for technological development—is a concept somewhat different from that usually mentioned, especially by the courts, in which patents have been regarded as being merely a personal reward to the inventor for making his invention; but the newer viewpoint is gaining increasing acceptance, and it may have important consequences since it emphasizes the way in which patents can confer their benefits upon our entire society.

Originally a grant from the sovereign to a favored subject, like those monopolies on the sale of some such necessary substance as salt or bread, the patent was early distinguished as a benevolent force, and was specifically exempted from the statute which abolished all other monopolies throughout England in 1623.

Monopoly or not?

Some now say that it is not a monopoly at all, since it is granted in protection of property which had no existence before the invention that called it into being, and which would never have belonged to the public but for the patent. Others deny this, saying that no invention is so great that others would not reinvent within a short time. At least, if the patent is a monopoly, it is clearly one of a special and useful kind deserving protection, perhaps in the same way that society finds it prudent to grant and enforce a monopoly to a person in the services of his spouse.

Like marriage, however, a patent has come to be regarded as a contract affected with the public interest, and as a contract it has legal implications of interest to the development engineer.

The owner can transfer to others all the legal benefits of his patent by an assign-

> The Congress shall have power . . . To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.—*The Constitution of the United States,* Art. 1, Sec. 8.

ment in writing. He may do so as to any inventions that he may make in the future course of his employment, and this is the ordinary condition of engineering employment. When no such specific agreement exists, the employer may nevertheless claim a "shop right" in an employee's invention if made of company material or on company time. This shop right is personal to the employer and his business successors in that he has no right to sell his interest in it, but may only practice the invention and sell its produce free of royalty payments. The invention belongs *solely* to the employer, of course, if the employee was hired to invent it, since that was what he bargained for, and in such a case no specific written agreement is necessary, although frequently one is used to clarify or to adjust the rights of the parties according to their desires.

Such is the ownership side of the question. Beyond that, patents have great value to the engineer because of the prestige and reputation which they confer. Not all countries print the inventor's name on the patent but here, fortunately, the engineer can gain a distinct economic advantage from this impressive public record of his patent activity, both in advancement and in professional prospects.

This being so, what can he do to cultivate the patent field? First, he can keep his eyes open. Tricks and dodges used to coerce the forces of nature into man's employment are commonplace in technical work. Often they seem old, but sometimes they gain novelty by their employment in a new field, a new combination, or a new way. Hence, keep a record of things tried, things made, things done; even of ideas had. Beware of statements on the record that anything "didn't work" or "failed" to do this or that, if there is a possibility that it could ever be salvaged for any purpose whatsoever. Such words may defeat any claim which you might later wish to make that the earliest date of your invention was near that time.

During the ex parte or uncontested prosecution of an inventor's application in the Patent Office, he has a right to expect that the Office regard as being true every credible statement of fact that he will swear to.

When his "priority of invention" over that of another applicant comes into question, however, and the establishment of dates assumes extreme importance, he will find his unsupported testimony held insufficient to establish them under the rule which labels it "self serving," and his written records devoid of any credibility unless corroborated. Nothing that he now says or ever wrote, no drawing that he made, not even a model that he constructed at the time of his invention bears any weight at all, unless someone else is prepared to come to his support and say "I saw it then, I understood it fully, and it is true."

This, then, is why a technical notebook should be read and signed, periodically, by a witness who can understand it; why daily dating of the notebook is the better practice; why a new day is started immediately after the old, instead of on a new page which would show the suspicious opportunity of occasional gaps; and why bound rather than loose-leaf notebooks are the rule.

No Second Prize

True, an interference between inventors occurs in only a minor proportion of cases, but they are usually the important cases, and the rules by which the unsuspecting inventor must have guided his conduct in the distant past are strict and harsh. There is no second prize in this race.

The *Weekly Law Reports* contain a record of every patent interference, and in any week's issue you may find the sad record of some inventor who would have won out but for the fact that he failed to heed rules that he had never heard of at a time when he didn't even know that he was in a contest!

Here, then, are a few of the more important rules that apply to inventing, all of which can be broken with impunity if you are even moderately lucky but which can be vital to success, if the showdown ever arrives.

(1) Date and sign everything you write, and write everything you learn concerning an invention, preferably in a chronological record. Very often occurrences which are seemingly trivial carry great weight at a later time and, in any event, a record which is full, clear and comprehensive is much more likely to be believed. When others act for you in any capacity during the inventive period, if they may not be keeping the kind of records that you should keep, then *your* record of *their* activities should be as complete as if you had done it all yourself. It is commonplace for a desperate inventor to attempt to show that he procured supplies of special goods for making the invention on a given date, and it is equally common for him to be unable to prove that they were actually intended for use in that particular invention, because he had never written it down!

(2) Date and sign each sketch given to the draftsman. Make sure that the sketch is self-explanatory and that it is preserved. Years may elapse before it is needed, but it and the all-important first date on it are outstandingly good evidence, and they usually antedate the formal drawings by a substantial period, which is vital surprisingly often. See that the draftsman's initials and the correct date are put on the sketch as soon as he receives it. He will provide the indispensable corroboration, and his initials and the date, noted at the time, will provide credibility to his testimony.

(3) Likewise corroborate the notebook data at regular intervals by inviting a competent person to read, understand, date, and sign it at the foot of the notes.

(4) It is of the greatest importance that the record show persistent diligence in somehow advancing *every* idea which may later ripen into a patent, even though many such ideas are carried forward simultaneously. Order supplies, make some test, adjustment, computation, rerun, substitution, or otherwise forward each promising idea (and all the unpromising ones which you do not wish to abandon) at frequent intervals. Once a week would not be too often.

A Model Can Help

(5) The model is the most convincing evidence of invention that can be offered when properly corroborated, but it usually will be insufficient unless someone else has seen it operate, knows how it operates and knows *of his own knowledge* how it is constructed. A contest involving an electronic organ recently was lost because the witness to the first model, who saw the ordinary pitch pipe with an electrostatic pickoff screw inserted into it next to the reed, and heard the organ sound which it produced, was unable to say that she had personally cut the rivets with which it was originally held together, and ascertained the fact that it *did* contain a concealed reed and that the inner end of the pickoff screw was actually, as well as apparently, located next to the reed, at the time of the demonstration.

Save the model, if at all possible, or at least a revealing series of photographs of it, duly identified by the photographer's number thereon, and his records, or by his signature and date on the back, and fastened in the notebook together with the demonstration witnesses' acknowledgments.

(6) In testing a model to see if it is finally satisfactory, you must apply every test which is necessary to show that it would work satisfactorily under practical conditions of use. The inventor of an airplane carburetor failed to test it upside down. The inventor of a deicer tested it for temperature and for humidity but failed to combine the two. Secondly, you should not tarry after the invention is completed and properly tested.

While an invention which has been diligently developed is "actually reduced to practice," and a retroactive date of invention thereby determined for it when it is first properly and completely tested,

Robert H. Henderson graduated from the Rensselaer Polytechnic Institute in 1936 with the degree of Electrical Engineer, and joined the Modutrol Division of the Minneapolis Honeywell Regulator Company upon graduation. He held engineering positions successively with Good Housekeeping Magazine, The Sperry Gyroscope Company, and the Materials Laboratory of the New York Naval Shipyard. Mr. Henderson attended Brooklyn Law School, where he received a Bachelor of Laws degree in 1951 and was admitted to the Bar of New York and of the United States Patent Office. He joined Western Union in 1952 as a member of the Patent Department, where as a patent attorney he engages in the preparation and prosecution of patent applications and related activities for the company.

adjusted and used, further delay to extend the tests or the use before filing will surely place upon you the burden of showing that any intervening inventor was not the first, and if filing is long delayed may enable him to show that you have abandoned your right to a patent. This intervening inventor who thought of the idea after you did, but worked faster and filed first, is not entitled to the patent if you can produce good and sufficient evidence of what you have done, but he does have a tactical advantage because he is not required to have done any testing at all, and may therefore put you to your proof without submitting any evidence himself, by relying on his filing date alone if he chooses to do so.

(7) If a practical test in actual commercial use seems to be the answer, remember that the inventor must swear in the terms of the statute that the invention was "not in public use or on sale in this country for more than one year prior to his application." A year of public use runs very fast to raise this statutory bar. If this kind of testing is imperative, and more than a year is needed, the bar must be avoided by creating an experimental use. This is done by making sure that the provable facts show a primary purpose of testing and perfecting, rather than of profit. Frequent or regular tests, inspections, adjustment and change help to show this purpose, and even avoidance of profits is sometimes undertaken to make this purpose clearly appear. Of course, any sale or offer of sale of the invention during this phase should be avoided and even the sale of its produce is better avoided, if the strongest case for patentability is needed.

(8) Beware of publication. Again remember that a statutory bar appears one year from the date of unrestricted publication of the invention, but here mere publication is an instant bar to patents in some foreign countries.

(9) Use your technical skill to visualize the entire breadth of your invention. Your patent will describe very closely the one method of practising your invention which you now feel is best and most important, but it is commonplace for a patent to have its value based on some secondary aspect which seemed relatively minor when written. Less than a tenth of Morse's telegraph patent is devoted to describing the relay system on which long-distance telegraphy was based. The remainder of this pioneer patent was unsuccessful.

(10) Be sure that what you write about the mode and manner of operation of the invention is correct. You are not required to know the ultimate details of theory on which it operates, and a mistaken explanation of this can be far worse than none at all.

Finally: Cooperation

The remaining injunction is one which should scarcely need stating, and that is to cooperate with the patent attorney. The strength of a patent lies mostly in the claims which it contains, and it is his duty to spread a net of claims around the invention through which infringers cannot wiggle. Trite as that may sound, it is a rare and refreshing experience for most patent attorneys to find a disclosure so thoughtfully prepared for his benefit that he can comprehend it in its entirety without extensive digging, rearranging, and requests for further information.

The quality of a patent can never be better than that of the invention which it covers, and is always somewhat worse, because no such document can be drafted perfectly. How closely it approaches complete protection of the invention depends largely on how thoroughly the attorney understands it, how precisely he can express this understanding, and often on how lucky he is.

Reference

[illegible]

SWITCHING SYSTEM PLAN 38

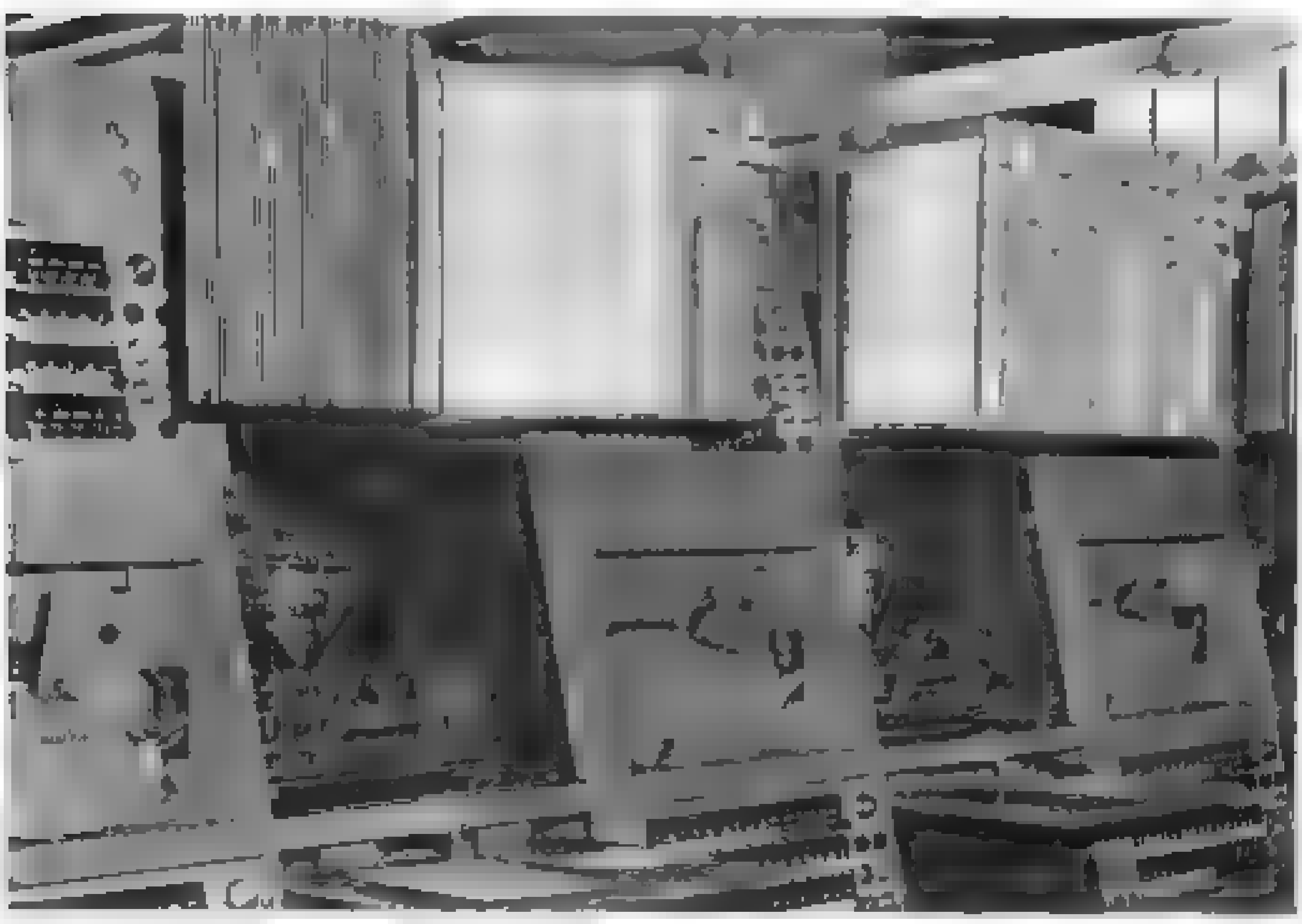


Photo H 2531

A group of route chart leaves of the 7355 Type for 3-column sheets is shown installed on Route Chart Leaf Holder 9057-A mounted at the front of Printer Perforator Table 4896 used in Switching System 38. The leaf holder has a maximum capacity of 81 Type 7355-A and Type 7355.1-A leaves, which are identical except that the latter has provision for mounting Route Chart Tab 8894-A in four different positions on the upper outer edge of the frame; this leaf is used at the start of each alphabetical listing. The lower printer-perforator compartment door, which is shown open in the horizontal position, carries the number sheet holder and a paper clip for miscellaneous notes.

HOWARD C. ISAACS, Senior Project Engineer, Switching Equipment and Systems

Shunt Monitor Appliqué

In connection with a contract with the U.S. Air Force to install new technical control centers at overseas points, it was necessary to design a Shunt Monitor Appliqué unit. This unit must have a high input impedance and be capable of sampling the voltage to ground at various points on a circuit and translating it into a signal output capable of operating a teleprinter or polar relay

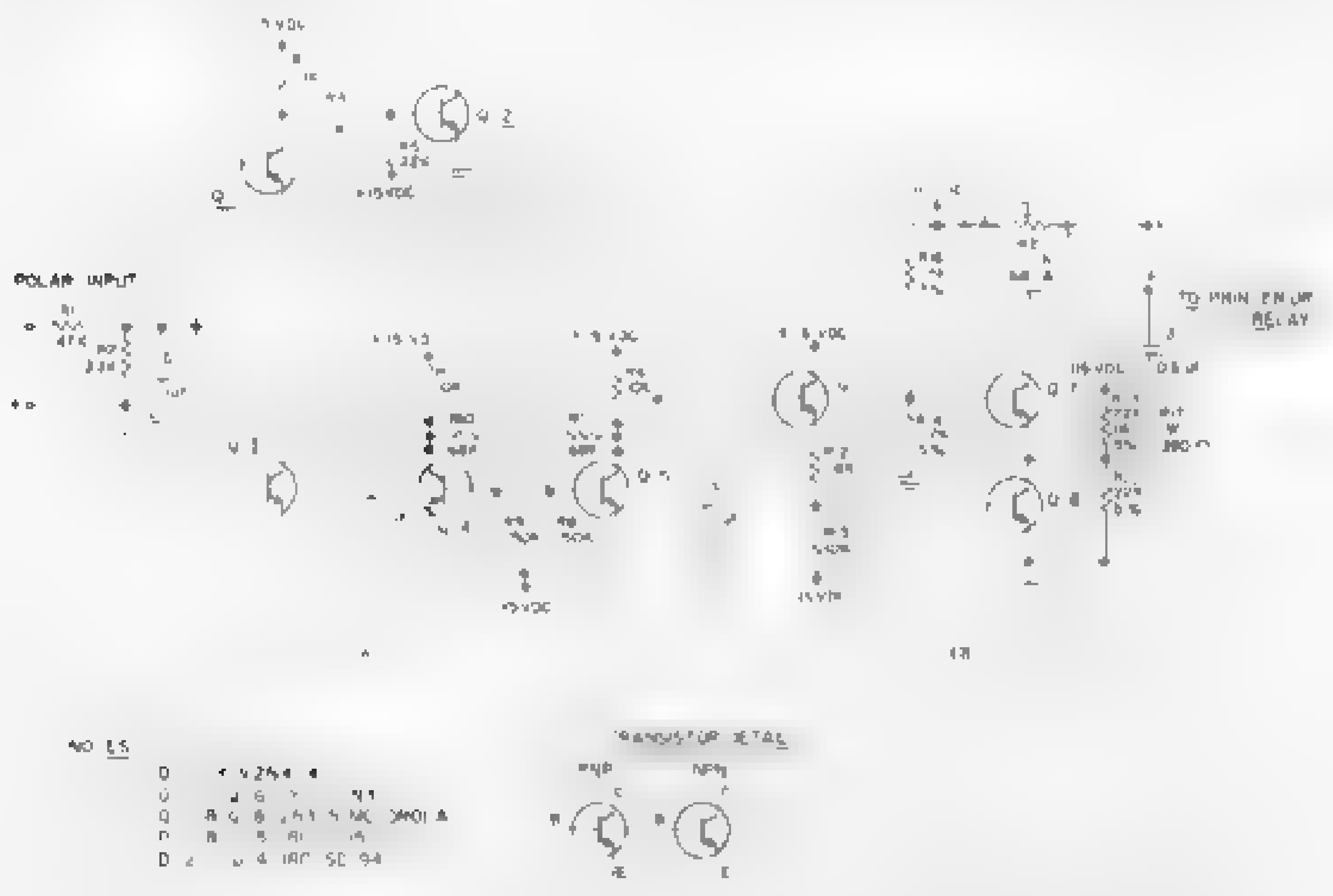


Figure 1 (A) and (B). Schematic diagram of input and output circuits

The input impedance must not be less than 50k ohms and the unit should operate on voltages between plus and minus 5 and 60 volts. The monitor should work on polar signals only and should not respond to make-break signals; it should be capable of delivering 70 milliamperes to a teleprinter or to the main line winding of a Type 202-A polar relay. The device must be self-contained, having its own power source, operating from a primary supply of 120-volt, 60-cycle alternating current.

The shunt monitor appliqué plug-in unit is used to permit bridged (shunt) monitoring of an operational telegraph circuit by a teletypewriter page printer without degradation of the monitored circuit. These units are to be used within the monitor printer console and quality control console of the technical control centers. The unit responds to 60-volt, 20-milliampere polar signals at rates up to 100 bauds. The output is arranged to operate the printer selector magnets with less than 1-percent distortion in the monitored signal.

The monitor printer console is used with the traffic patching facility which provides a means of patching equipment and lines for traffic and or maintenance

purposes. The shunt monitor is connected to the receiving and sending leg circuits at the traffic patching facility. Provision is also made for connecting the shunt monitor to the telephone ringdown facility which provides for voice order wire communication.

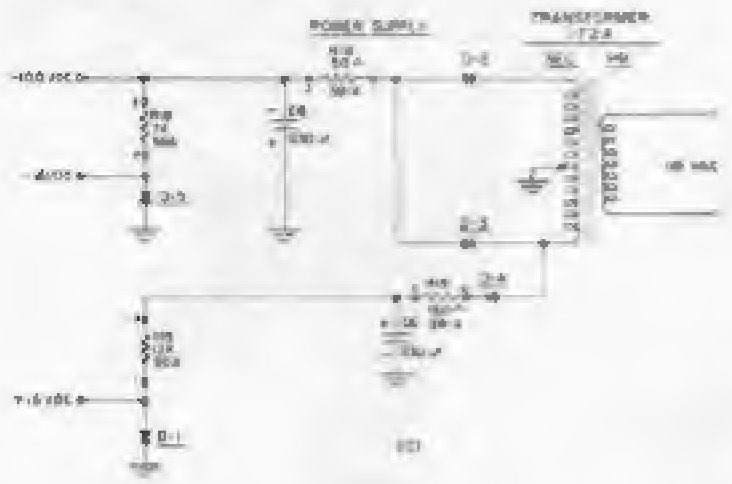


Figure 1 (C). Schematic diagram of power supply

Figure 1 is a schematic diagram of the unit. For purposes of explanation, the shunt monitor appliqué unit is divided into three groups: (A) the input circuit, which includes a d-c amplifier (*Q1* and *Q3*), and inverter (*Q2*), and a flip-flop (*Q4* and *Q5*); (B) the output circuit, which consists of an emitter-follower (*Q6*) and an output amplifier (*Q7* and *Q8*); (C) the power supply, composed of a transformer, a full-wave rectifier, a half-wave rectifier, and various regulating diodes.

Input Circuit

The input impedance of the monitor unit is approximately 50k ohms to prevent loading of the monitored line. The input signal is polar and may range from a minimum of plus or minus 5 volts to a maximum of plus or minus 60 volts. Transistors *Q1* and *Q3*, comprising the d-c amplifier, are complementary, *Q1* being a PNP type transistor and *Q3* being an NPN type. Temperature instability of the d-c amplifier is negligible since the low value of resistor *R2* necessitates a large value of I_{co} to change the bias.

Transistor *Q1* drives the inverter-transistor Q2. With a polar signal at the input, transistors *Q2* and *Q3* are always in opposite states. The conducting transistor (*Q2* or *Q3*) grounds the collector of its associated transistor of flip-flop *Q4* and *Q5* if it is not already grounded. Flip-flop *Q4* and *Q5*, a basic Eccles-Jordan circuit, is switched by grounding the appropriate (off) transistor collector. With make-break signals, however, the state of the flip-flop will not change when the input goes open, since transistors *Q2* and *Q3* will be nonconducting. This circuit ensures that the monitor will not respond to make-break signals but only to polar signals. The output from transistor *Q5* (plus or minus) drives transistor *Q6* associated with the output circuit.

Output Circuit

Transistor *Q6* supplies a positive or negative bias to transistor *Q8*, depending on the state of transistor Q5.

The output amplifier is composed of two transistors connected in series. This series arrangement is required for operation at 100 volts, since this voltage exceeds the voltage rating of one transistor but may safely be divided between the two transistors. The base of transistor *Q7* is biased negatively while the base bias of transistor *Q8* is dependent upon the condition of transistor *Q6*. However, when transistor *Q8* is biased to cutoff, transistor *Q7* is also biased to cutoff. Conversely, when transistor *Q8* is biased to conduction, *Q7* is also biased to conduction, grounding output terminal number 4. Transistors *Q7* and *Q8* are power transistors, capable of withstanding the momentary increase of power dissipation resulting from the removal of either the teleprinter or the polar relay from the output circuit.

Power Supply

The shunt monitor appliqué unit contains its own power supply, requiring only an external power source of 115 volts alternating current. A center-tapped transformer and full-wave rectifier supplies minus 100 volts direct current. The minus 100 volts direct current is tapped

to obtain minus 15 volts direct current. Zener diode *D5* acts as the regulator for this voltage. A half-wave rectifier is used to obtain plus 15 volts direct current. This voltage is regulated by Zener diode *D1*.

* * * * *

Figure 2 is a photograph of the packaged unit which is currently in service at Siegelbach, Germany and San Pablo, Spain where it is performing its function satisfactorily.

The author wishes to give credit to the people who contributed to this work. W. J. Wichtendahl and B. Lukaschewsky did most of the design and testing, E. J. Chojnowski was Project Engineer in charge, and H. E. Buchwald packaged the unit.

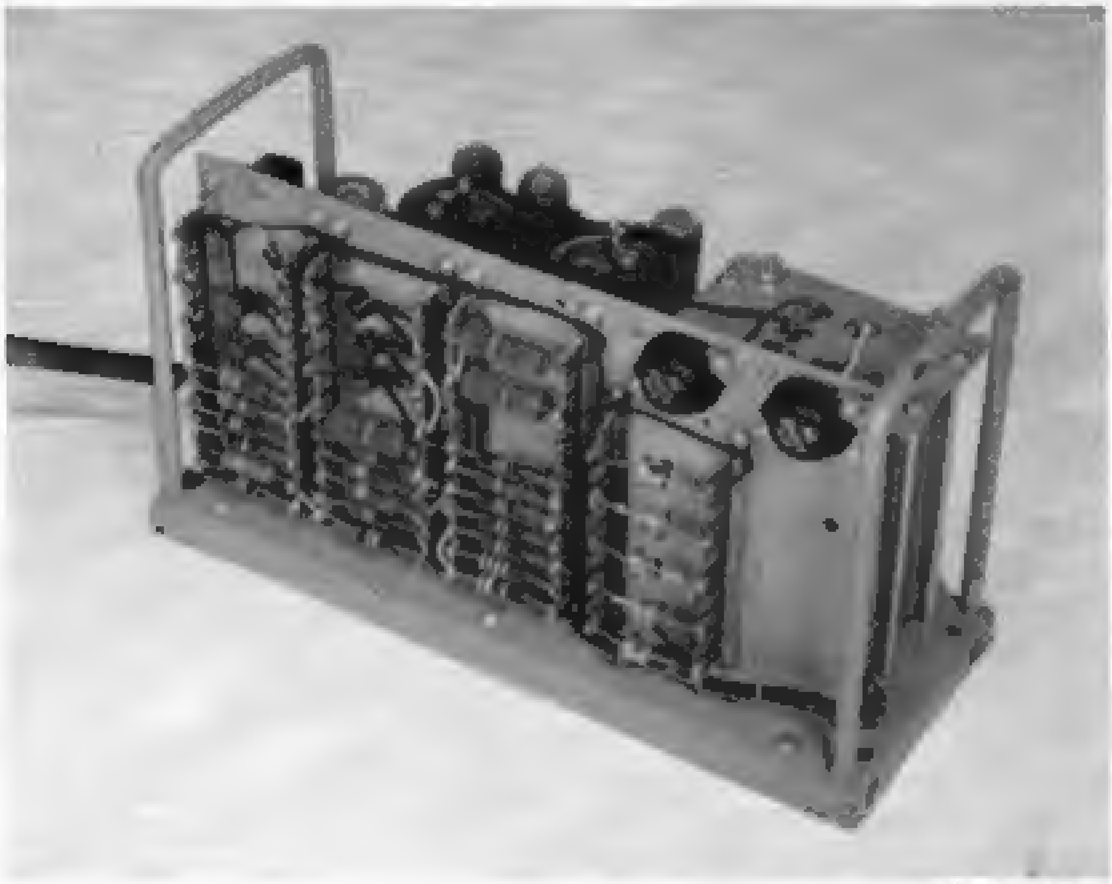


Photo R-11,852

Figure 2. Shunt monitor appliqué unit

A biographical sketch of the author appears in the January 1956 issue of Technical Review.

Patents Recently Issued to Western Union

Facsimile Telegraph Apparatus

C. Jelinek, Jr.

2,912,496—November 10, 1959

Provides means for compensating the line widening which tends to occur in facsimile scanners due to aperture effect further accentuated by the nonlinear amplification usually needed for the purpose of suppressing effects of varying copy density. A spike is developed from each signal pulse, in phase with its leading edge and of equal magnitude, and this is fed back in opposing polarity to effect a shortening of the original signal pulse.

Optical Scanner

R. D. Parrott

2,912,497—November 10, 1959

In a stationary slot and rotating spiral type of flying aperture for a facsimile scanner, this invention provides a substantially square aperture configuration of constant size, and with the leading side parallel to the direction of the scanning line. It is accomplished by using an involute type of spiral in which the base circle tangent of the spiral and the slot intersect substantially mutually perpendicularly and so provide sharply rising, uniform signals. If an Archimedean spiral were used the aperture would be of inconstant size, and the intersection would be at an acute angle to give a wedge-shaped approach with attendant generation of nonuniform, slowly rising signals.

Message Paper Cutter

E. W. Hewitt

2,912,501—November 10, 1959

A message sheet severing mechanism for attachment to a page type teleprinter wherein upon completion of a rotation of the platen, equivalent to a standard message length, cam contacts close to energize a pair of rollers which grip the leading edge of the sheet and tension it across a stationary, convex curved cutting blade. The severed sheet drops into a bin where it is held until released by an end-of-message signal. In the case of a multipage message, the pages are accumulated and then released simultaneously.

Facsimile Phasing and Repeating System

A. S. Hill

2,914,607—November 24, 1959

A repeater for interconnecting facsimile transmitters and receivers each of which normally transmits phasing pulses, as to a central office concentrator, but not to each other. To accomplish phasing, the repeater includes a storage recorder of at least one line, the stored period representing the phase difference between the transmitter and the recorder. As illustrated, the transmitter signals to the central office by dialing means the number of the desired called receiver; the lines are then manually connected by a cord circuit repeater and phasing of the two machines followed by message transmission proceeds automatically.

Facsimile Transmitting System

C. Jelinek, Jr., J. H. Hackenberg

2,919,304—December 29, 1959

A facsimile scanner and modulator adapted for ready conversion by a patron, by simple switch means, for handling message material of uniform density accompanied by linear amplification, or nonuniform density accompanied by nonlinear amplification, and either positive or negative in character. In all cases the scanner clamps to the copy background to produce a signal so low as not to mark the copy while scanning background areas. A simple line-up procedure for contrast, white and black levels, and modulator balance is described.

Telautograph System

G. H. Ridings

2,919,305—December 29, 1959

A telautograph system in which the X and Y pen movements are operated by amplitude modulations of the positive and negative half waves of continuous alternating current, e.g., 60 cycles. A single ungrounded loop is used for the writing currents thus avoiding the effect of ground potential. Paper advance, pen lift, and send-receive control are d-c operated over a simplex connection between the two wires in parallel and ground.

Frequency Modulated Oscillator With Distortion Cancellation

K. R. Jones

2,923,892—February 2, 1960

A two-tube reactance type frequency modulator for the subcarrier of microwave systems characterized by low distortion and simplicity of adjustment in service as compared with the pair of balanced oscillator-modulator chains which it displaces. The oscillator tank circuit is embodied into the intertube coupling in such a manner that a 180-degree phase inversion occurs as the signal passes from the anode of the reactance tube to the anode of the oscillator tube. Then by anode current adjustment the oscillator can be made to generate distortion components of the proper magnitude to cancel the like components coming from the reactance tube.

Telegraph System

G. G. Light

2,929,864—March 22, 1960

A duplex operated multistation telegraph circuit in which the push-button type central office initiates an invitation sequence only upon receipt of an invitation request (40-millisecond open) from a way station, and sent only when the circuit is idle, thus avoiding unnecessary interruptions to central office or way station sending. High-priority messages from all way stations are accommodated first. Way station message equipment is separated from the line by a control unit which intercepts all nonmessage characters to prevent printing thereof. At the central office, an automatic numbering machine for each station inserts message numbers on each incoming message, and for outgoing messages adds the start of message combination and the way station identification to the message tape when a way station push button is pressed. A number of safety and supervisory features are provided.

Transmission Test Apparatus

J. E. Boughtwood, A. Boggs, T. A. Christie

2,929,875—March 22, 1960

Apparatus for measuring bias, characteristic and fortuitous distortion in high-speed telegraph signals comprising essentially a common adjustable frequency oscillator which sends squared and differentiated signals via a first path to step an electronic distributor, which is shown as a beam type tube, to send into a signal pattern selector switch and thence into the line or device under test. Half lengths of selected signal pulses returned from the line, either leading or trailing, are compared in a coincidence circuit with like reference signals produced in a second similar path but including a phase-shifting circuit to compensate the delay of the transmission line. Departure from equality of the two signals provides a measure of the signal displacement and/or length variation.

Message Cutter and Conveyor

E. W. Hewitt

2,935,563—May 3, 1960

A two-part mechanism for addition to a telegraph page printer, the first part of which shears off the completed message blank upon receipt of suitable control signals at end of message, while the second operates a conveyor to engage the severed blank and eject it. It is a requirement that each message include or be followed by a sufficient number of line feeds so that the leading edge of the message blank will reach the conveyor.